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NASA Marshall Space Flight Center

Space Optics for the 21st Century

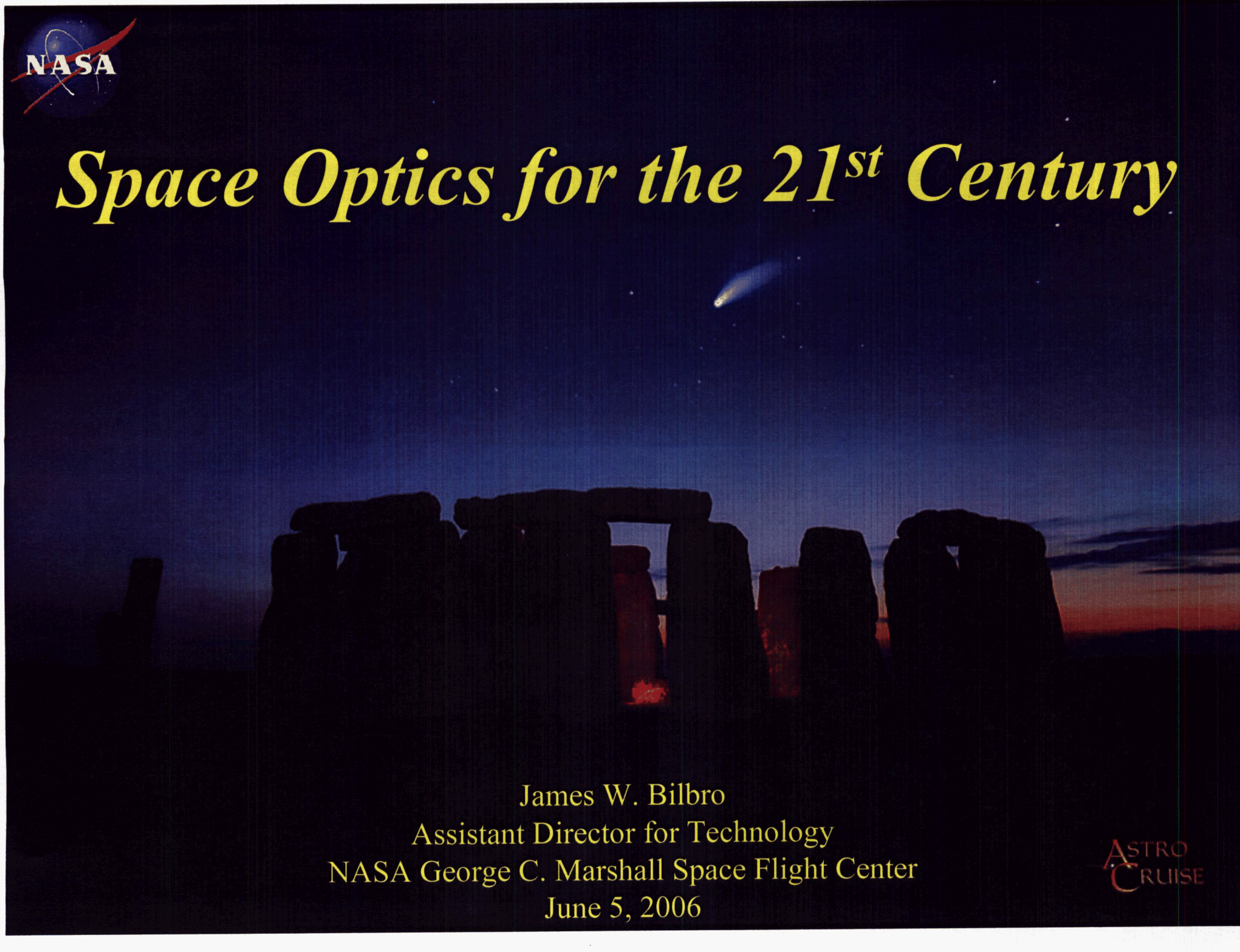
James W. Bilbro
Assistant Director for Technology/Chief Technologist
George C. Marshall Space Flight Center

Monday, June 5, 2006, 8:00 - 9:00 am

2006 Keynote Presentation

Technological advances over the last decade in metrology, fabrication techniques and materials have made a signifi cant impact on spacebased
astronomy and together with advances in adaptive optics offer the opportunity for even more radical changes in the future. The
Hubble Space Telescope primary mirror is 2.4 meters in diameter and weighs on the order of 150 Kg/m_2. The technology demonstration
mirrors developed for the James Webb Telescope had an order of magnitude less in area density and developments in membrane optics
offer the opportunity to achieve another order of magnitude decrease. Similar advances in mirrors for x-ray astronomy means that across
the spectrum future space based telescopes will have greater and greater collecting areas with ever increasing resolution.

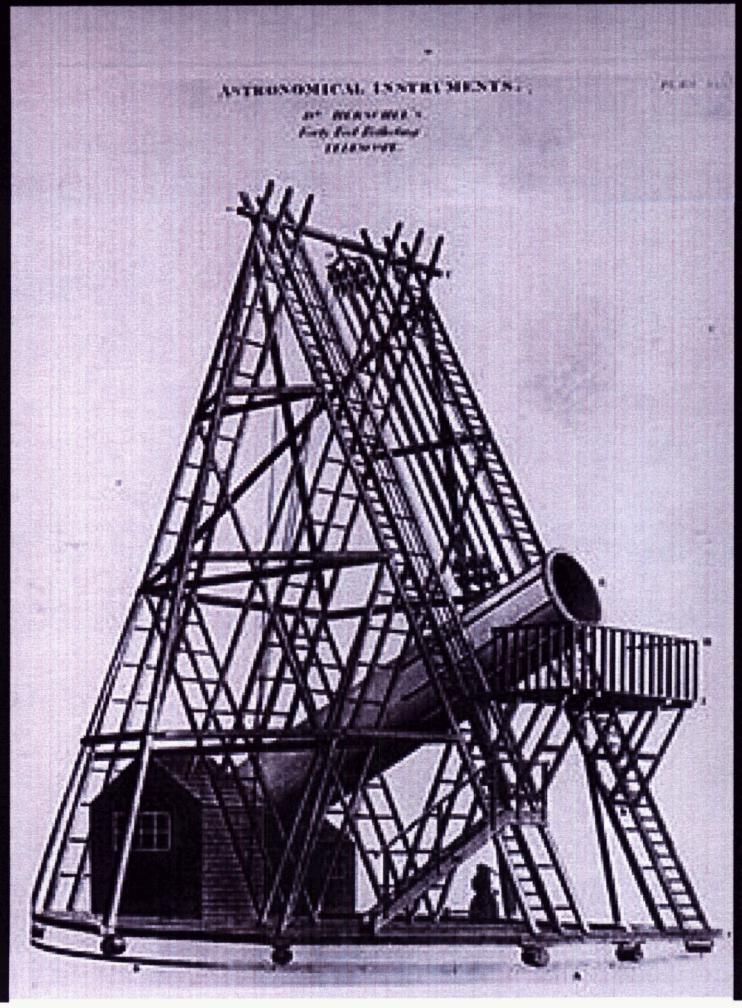
Dr. James W. Bilbro is Assistant Director for Technology/Chief Technologist at the George C. Marshall Space Flight Center. He received
his BSEE at Colorado State University (1969); MSE at University of Alabama in Huntsville (1977); and completed course work and residency
requirements for PhD in Optical Sciences at the University of Arizona (1983). Dr. Bilbro has over thirty fi ve years of engineering
and management experience in research and technology development primary in the areas of optics and coherent lidar. His specifi c
areas of expertise include the development of technologies associated with optical fabrication and test (particularly for x-ray optics) and
the development and application of Coherent Lidar systems. He has authored/coauthored over 70 papers and is co-holder of a patent
on the application of Doppler lidars to aircraft wake vortex tracking. He is a fellow and past president of the SPIE and a member of The
International Society for Optical Engineering, Optical Society of America, and Huntsville Electro-Optical Society.


NASA
Space Optics for the 21st Century
James W. Bilbro
Assistant Director for Technology
NASA George C. Marshall Space Flight Center
June 5, 2006
Astro Cruise

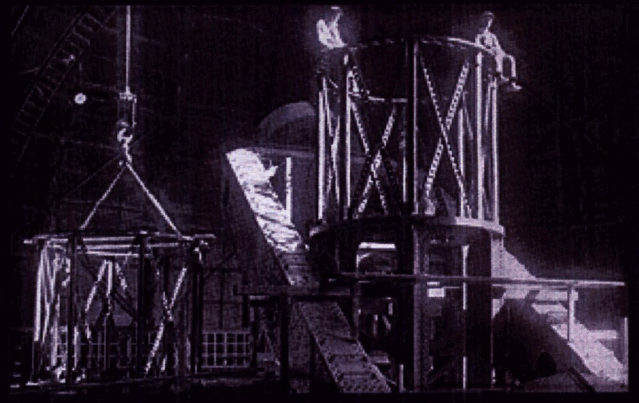
Archimedes vs. the Romans

Telescopes Through Time

Gallileo



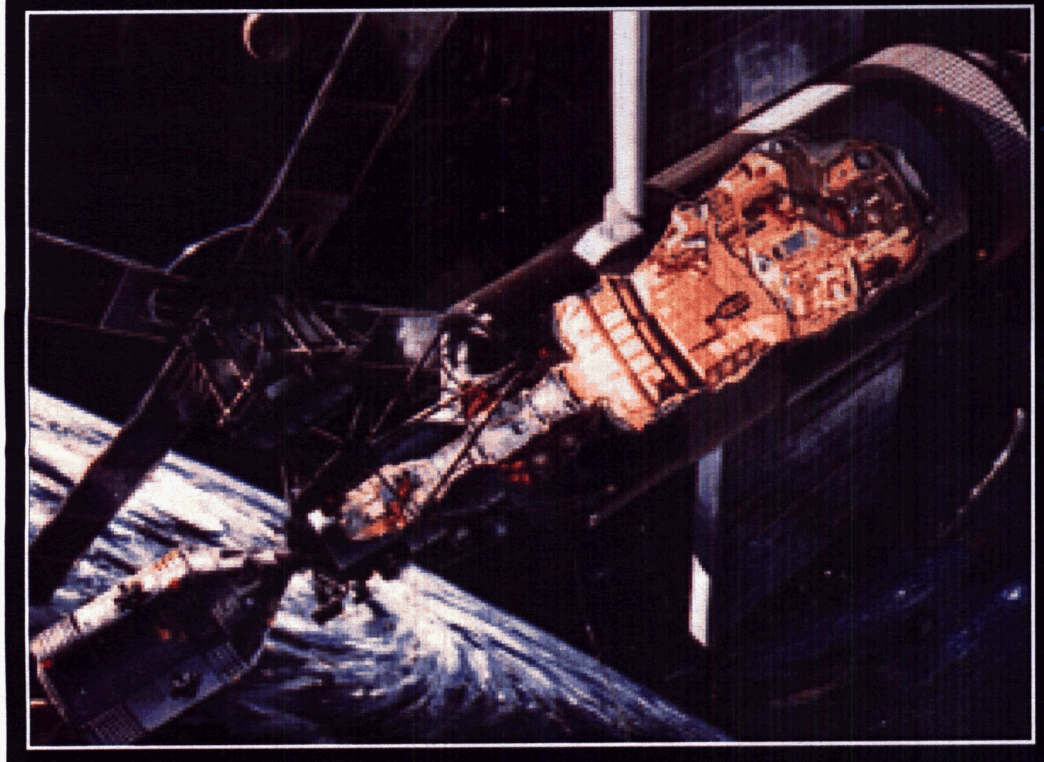
Herschel's 40ft
Great Telescope



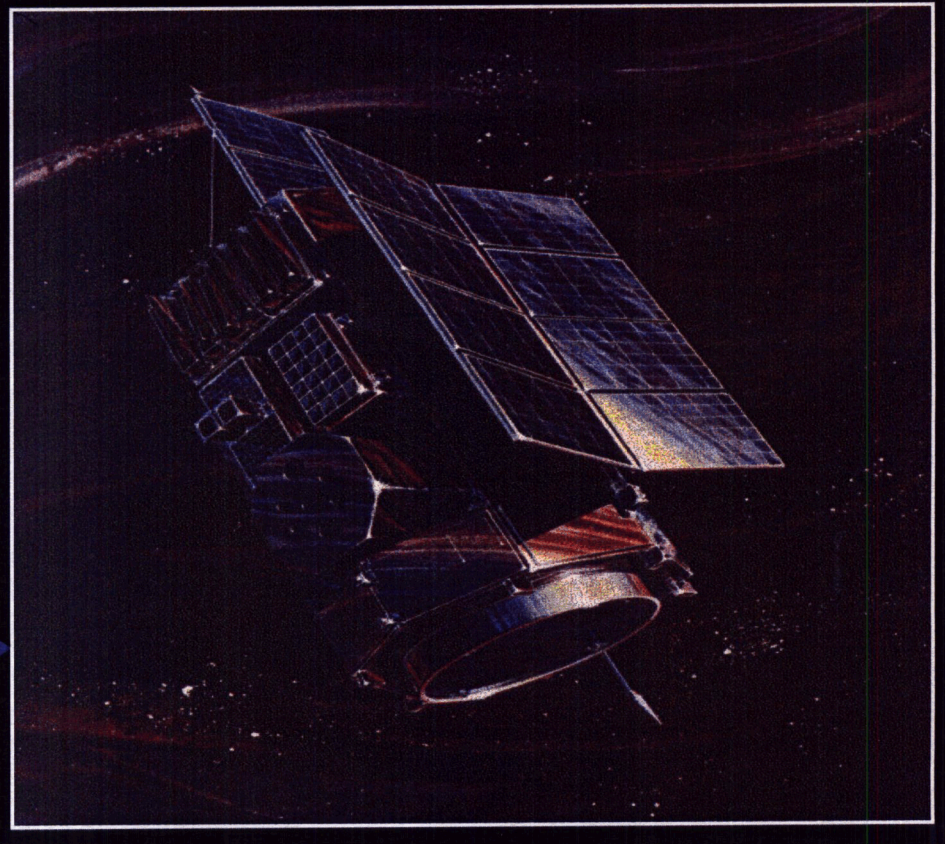
100" Hooker Telescope

200" Hale Telescope

Telescopes Through Time

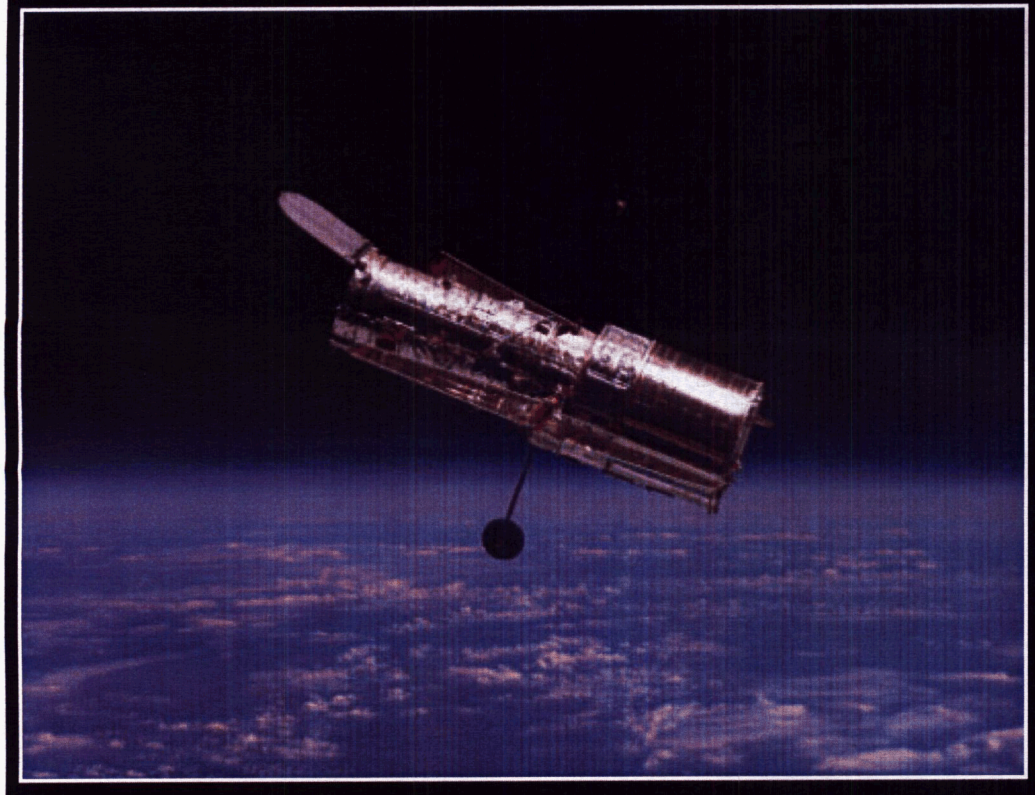


Apollo Telescope Mount

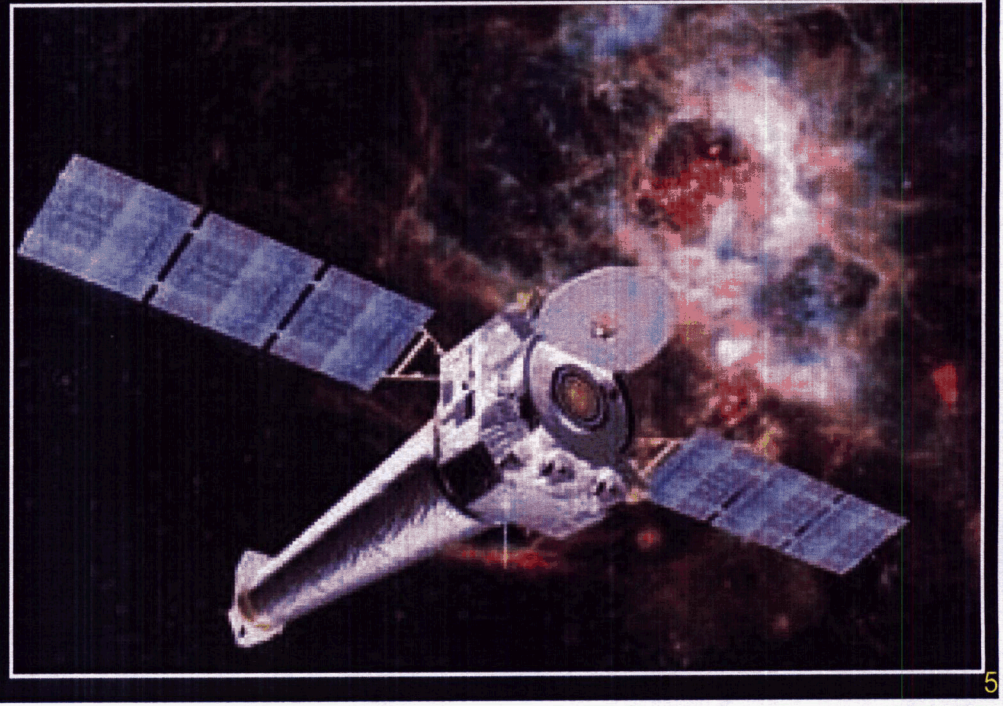


Einstein X-Ray Observatory

Telescopes Through Time



Hubble Space Telescope



Chandra X-ray Observatory

A Vision for the future

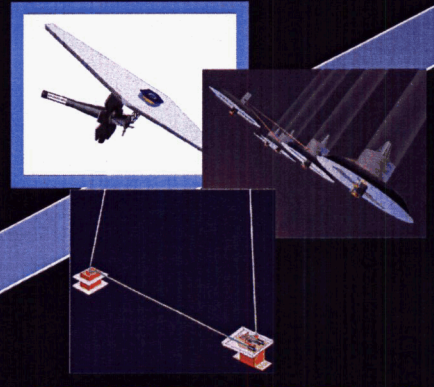
Toward Accomplishing…
… the Impossible!

100-1000m diameter

?

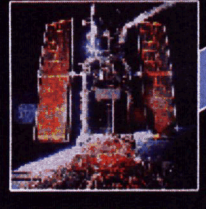
20-40m diameter

~10m diameter



Life Finder
Stellar Imager
Planet Image

2.4m diameter

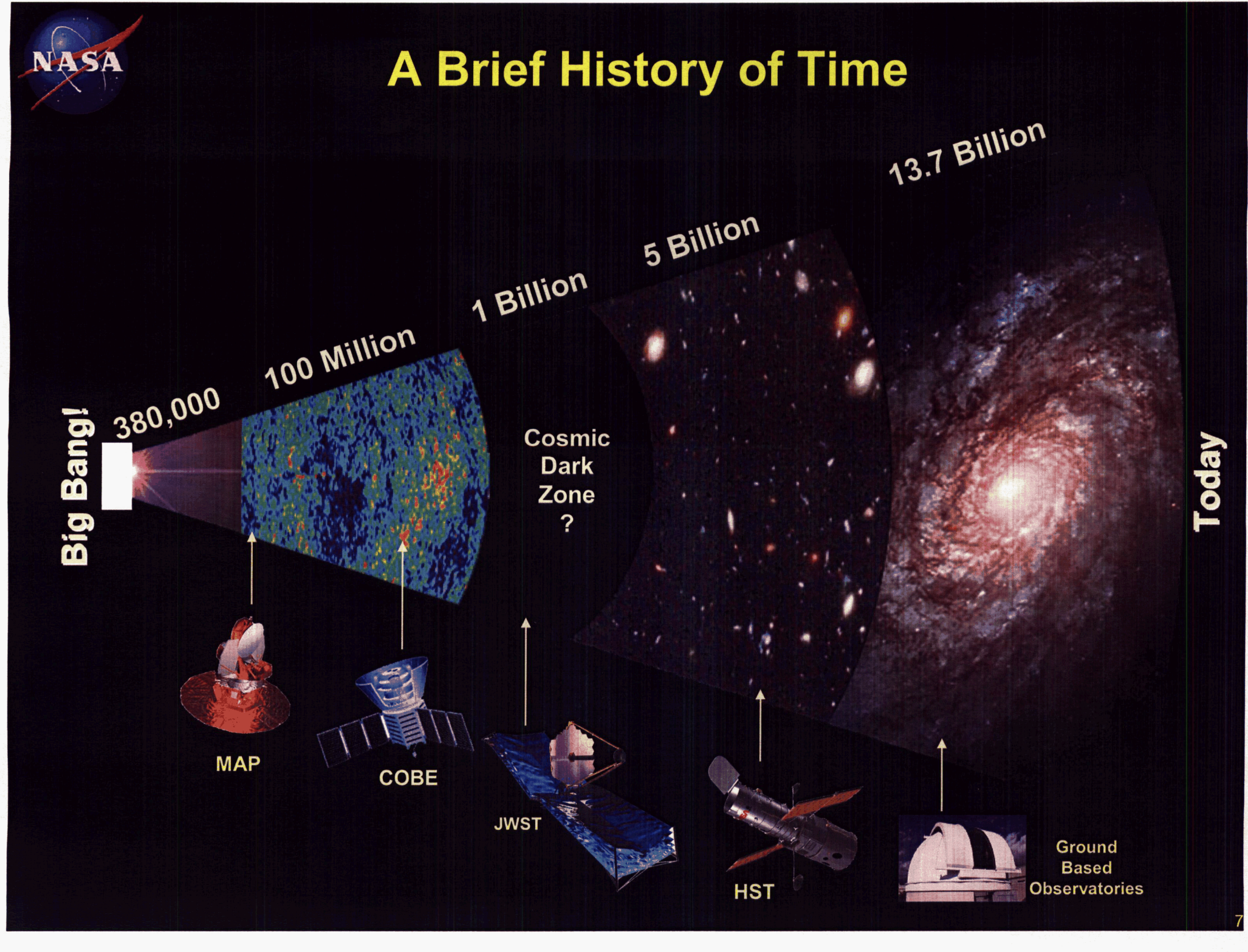


JWST, TPF, SAFIR

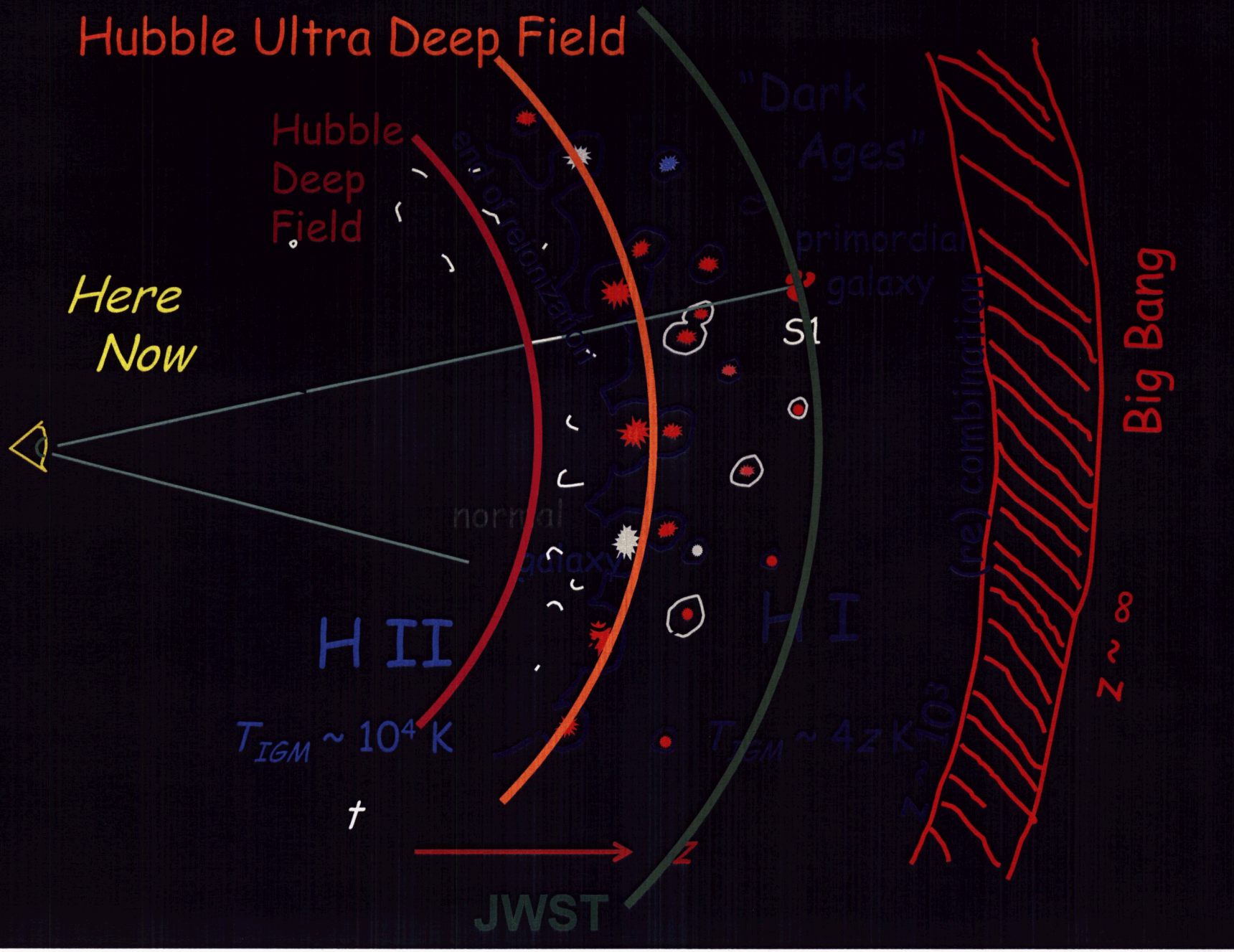
HST

Operational *Developmental* *Conceptual* *Unimaginable*

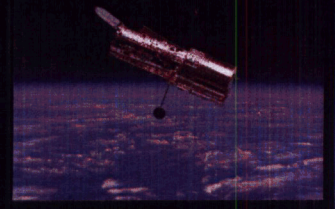
A Brief History of Time

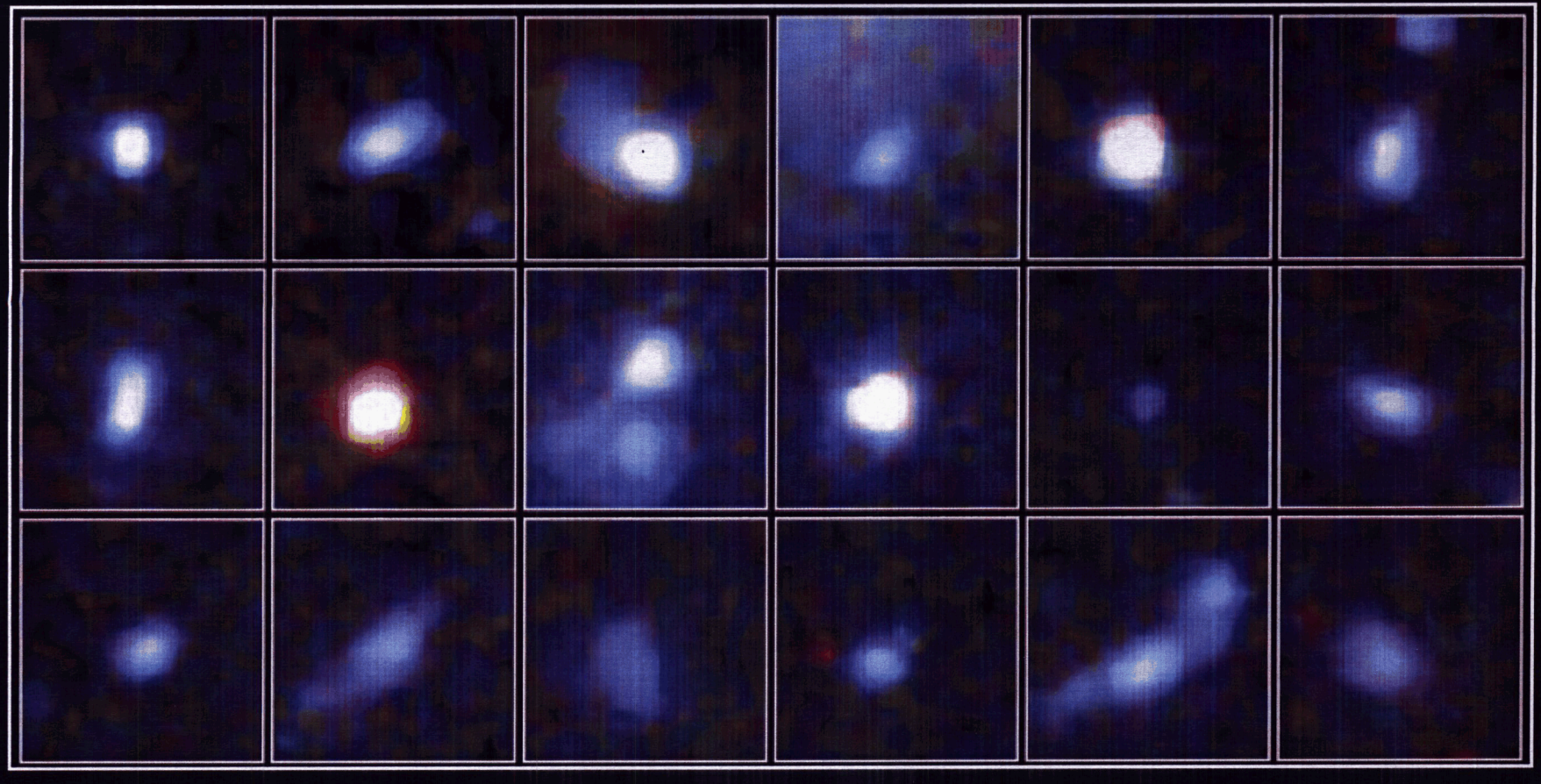


The Renaissance After The Dark Ages



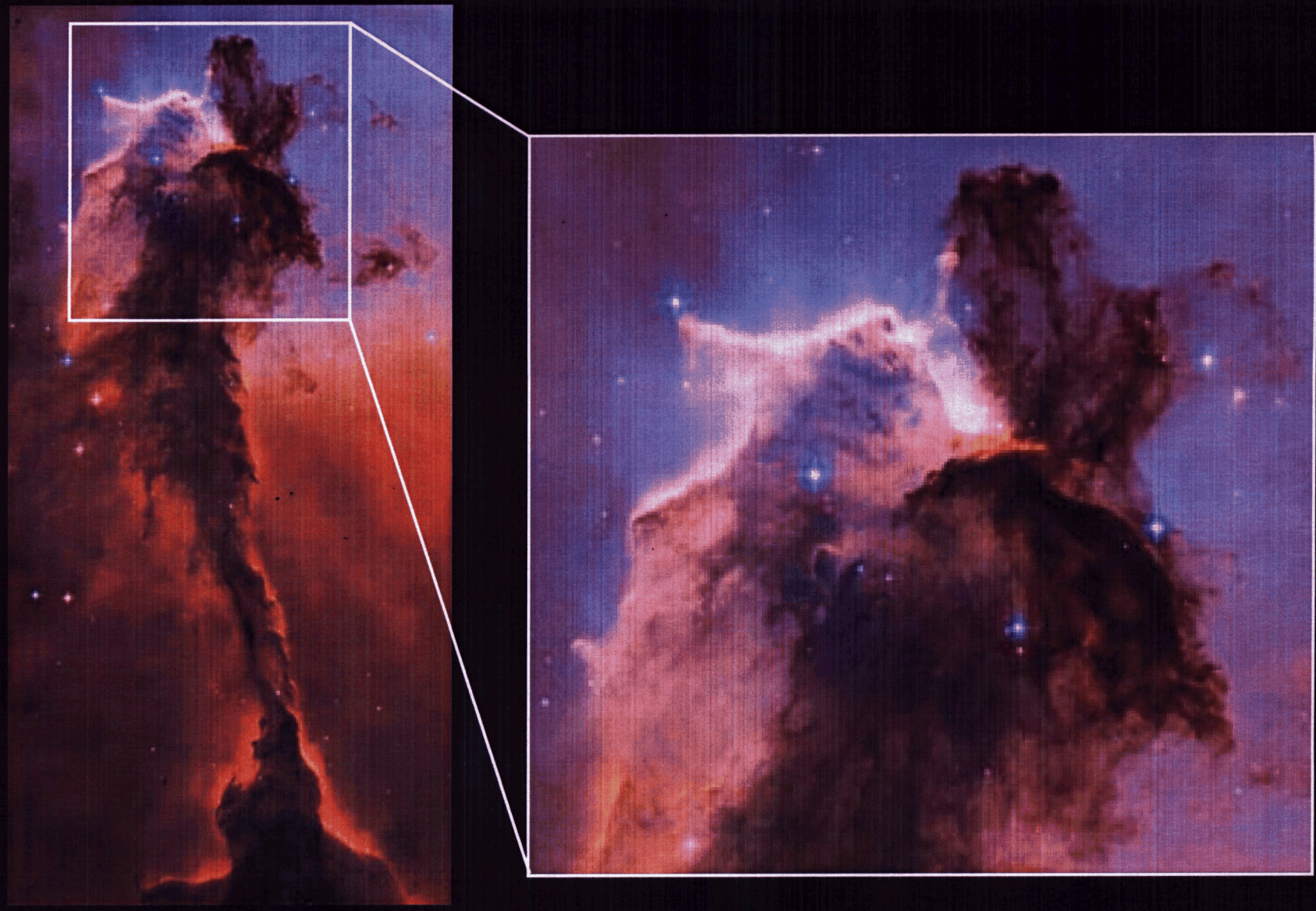
The Early Galaxies



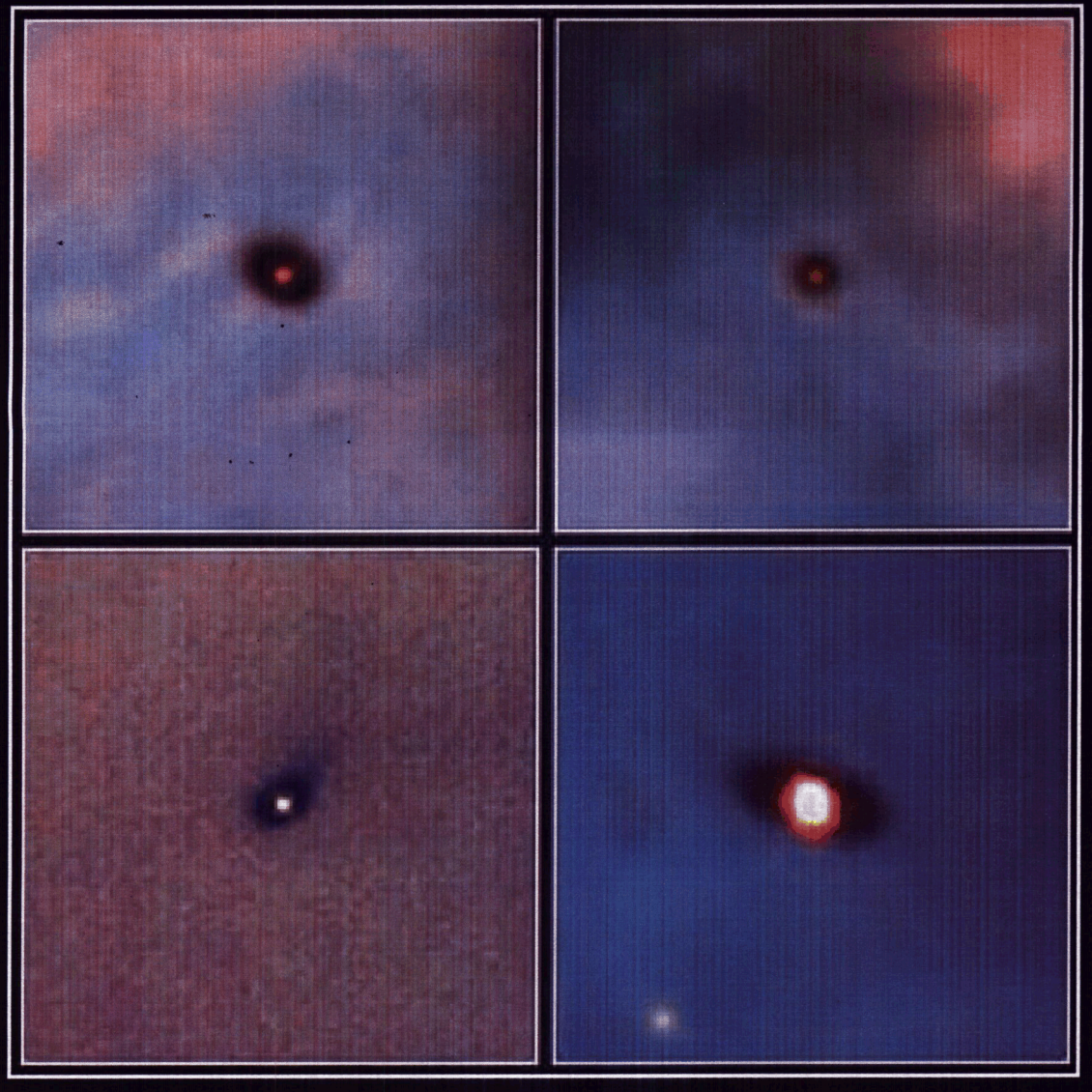


Galaxies Like Our Own

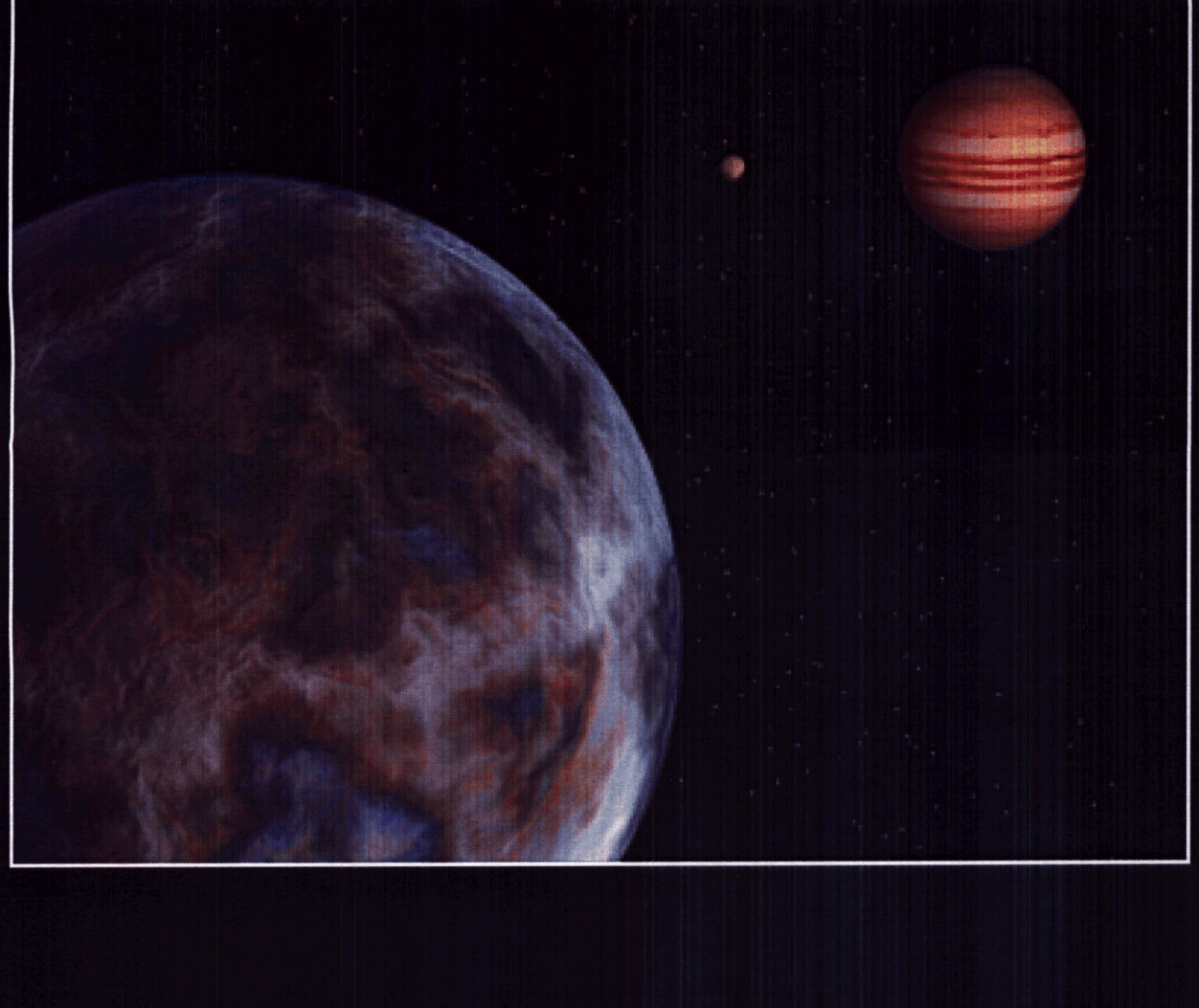
Formation of Stars



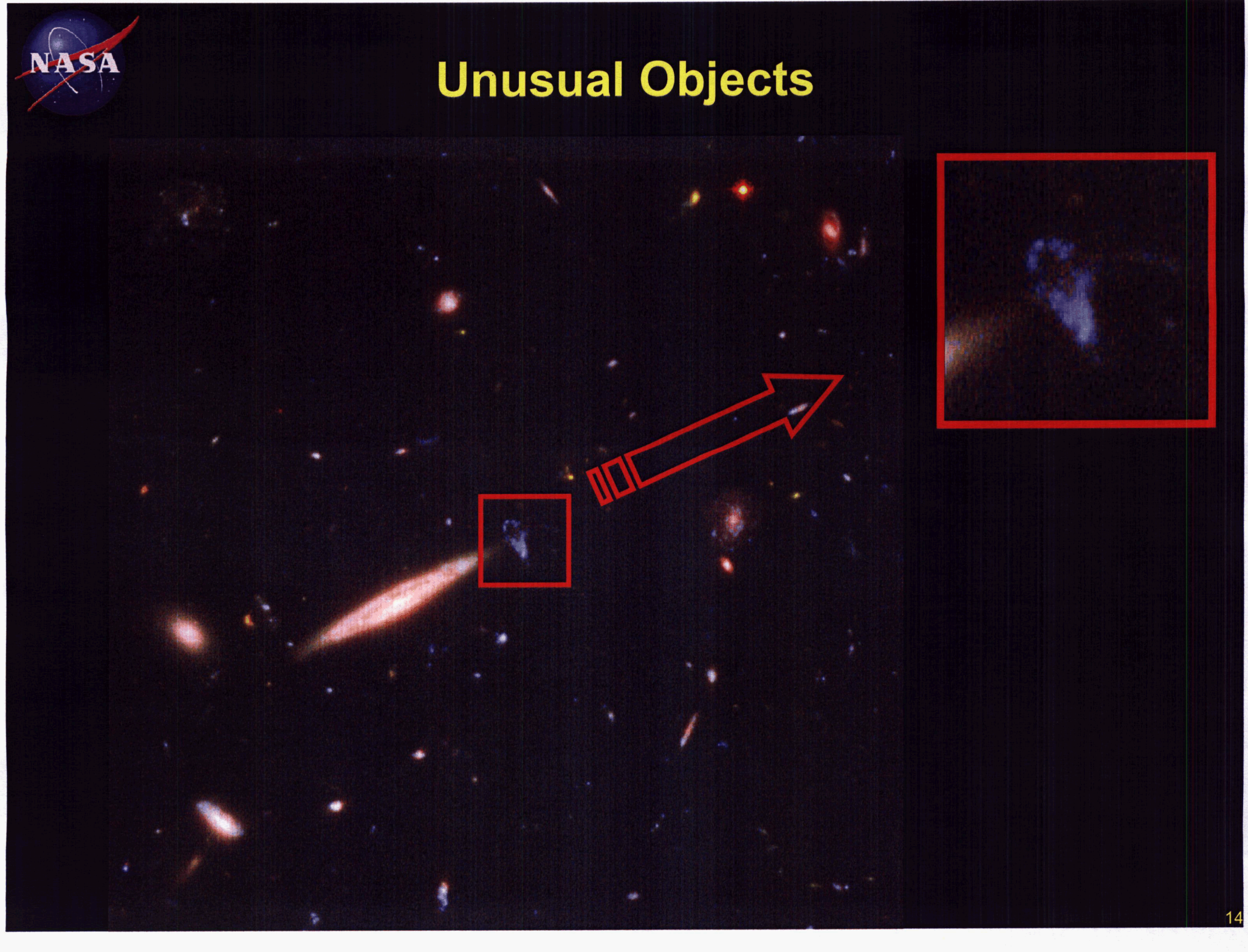
Formation of Protoplanetary Disks



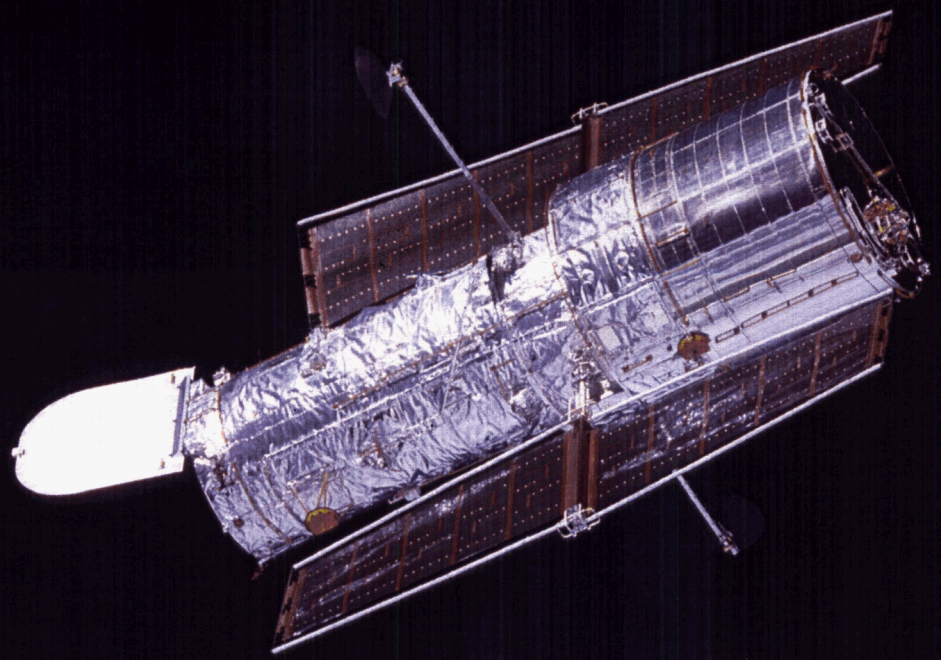
Detection of Extra-Solar Planets



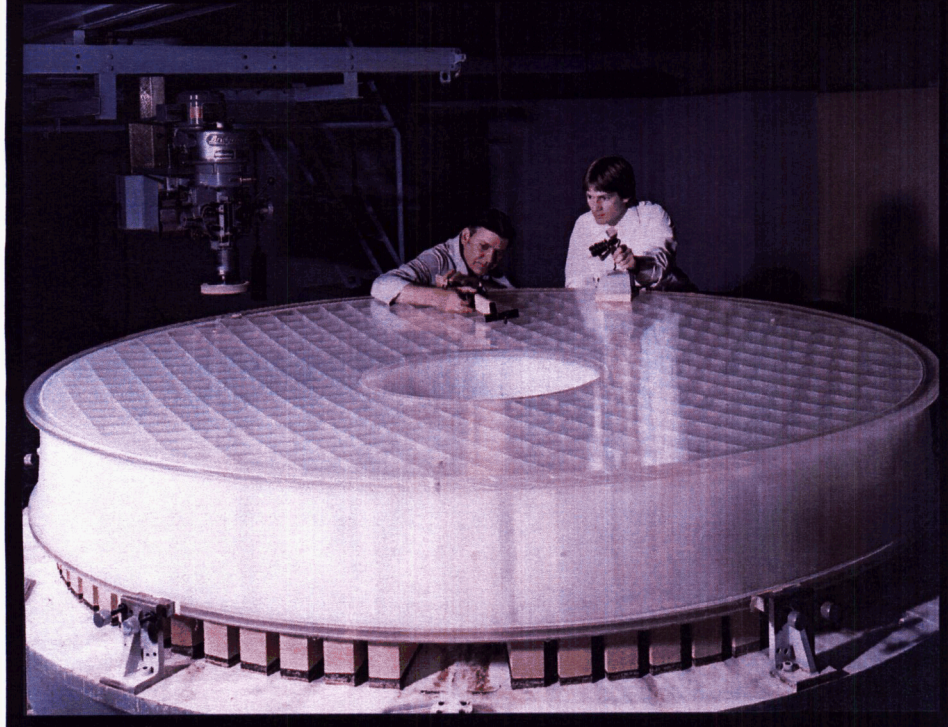
Unusual Objects

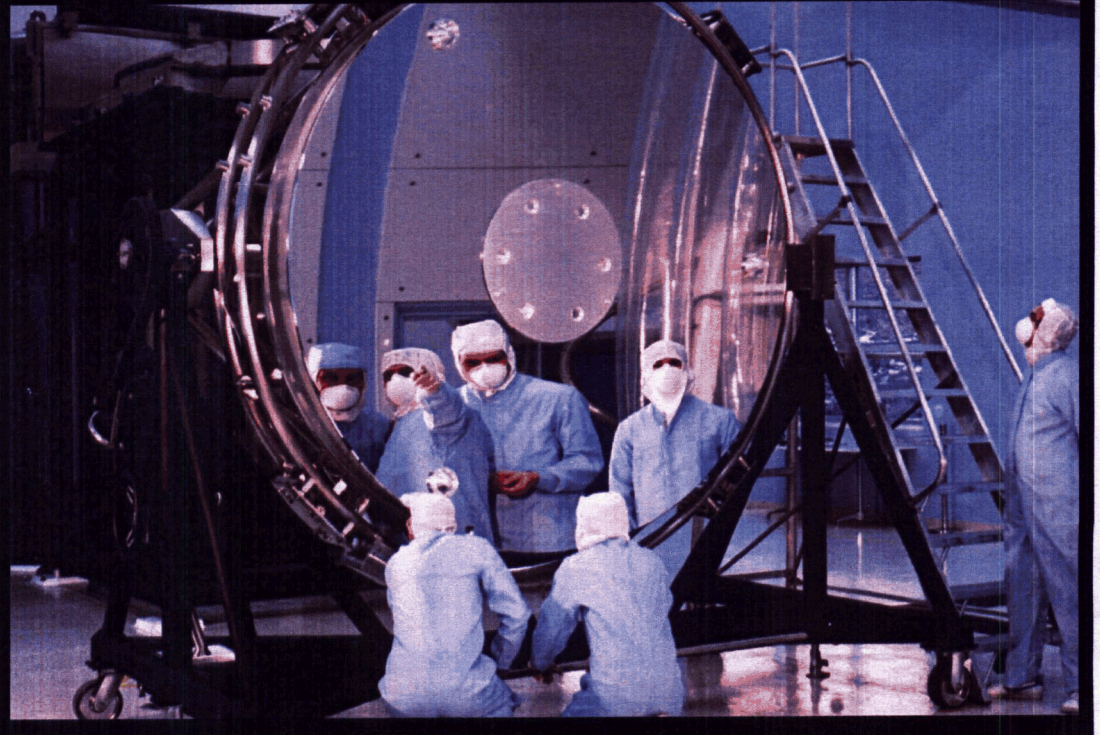


Hubble Telescope

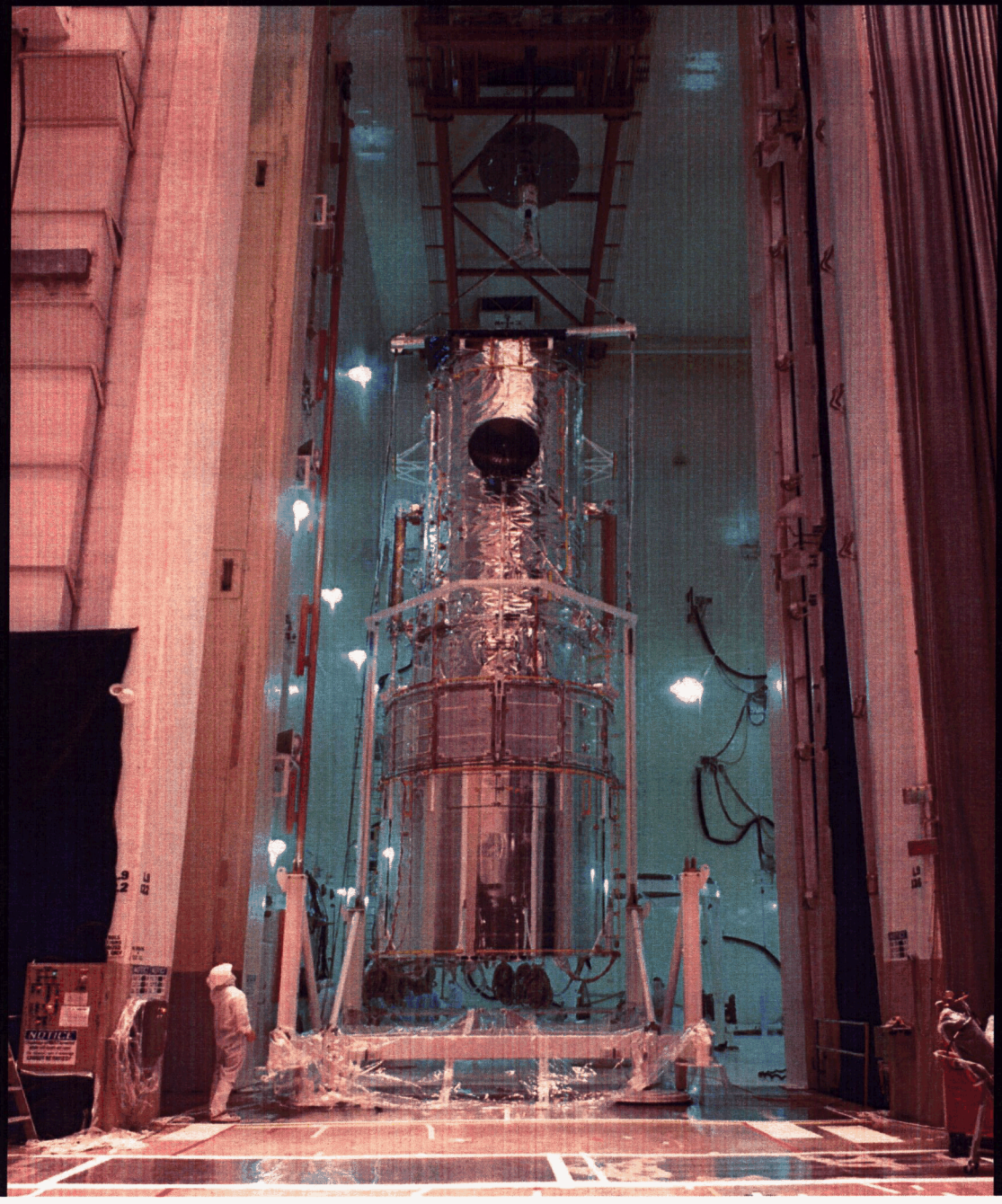


Hubble Telescope Primary Mirror

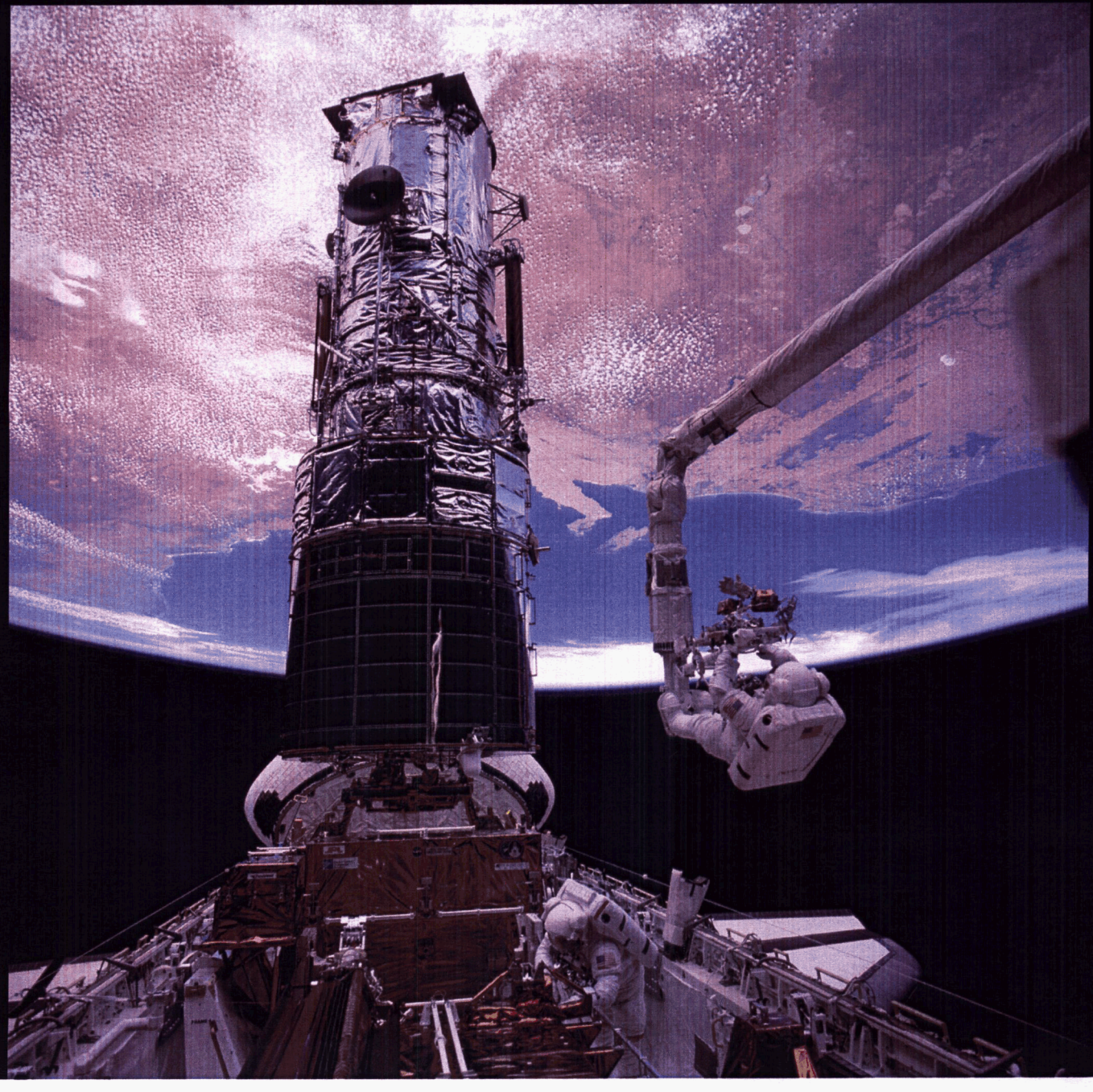




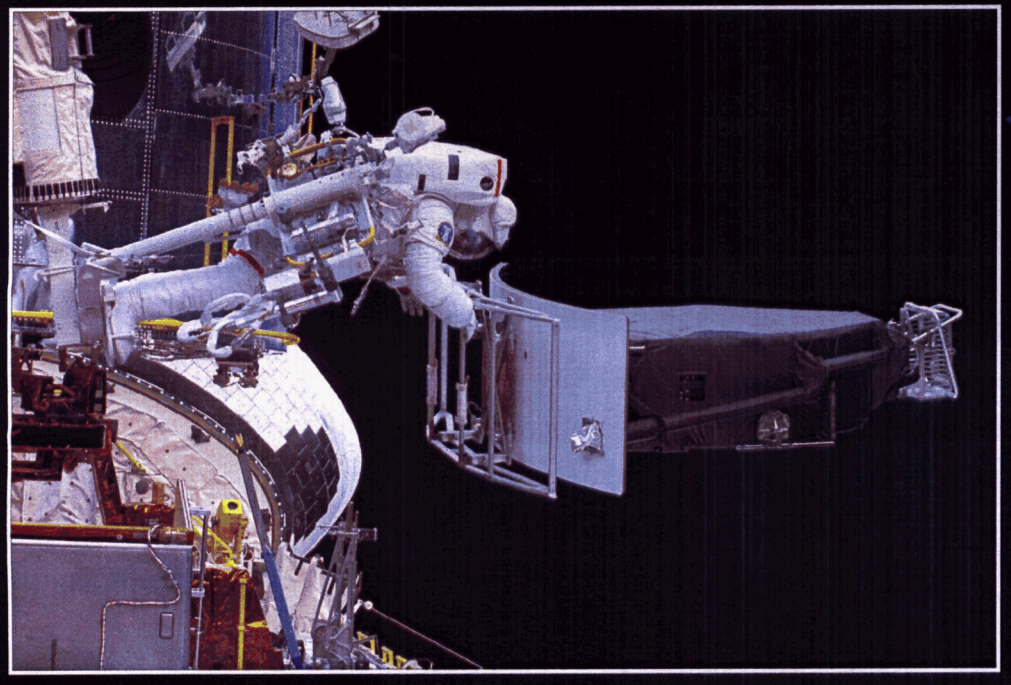
Hubble Telescope



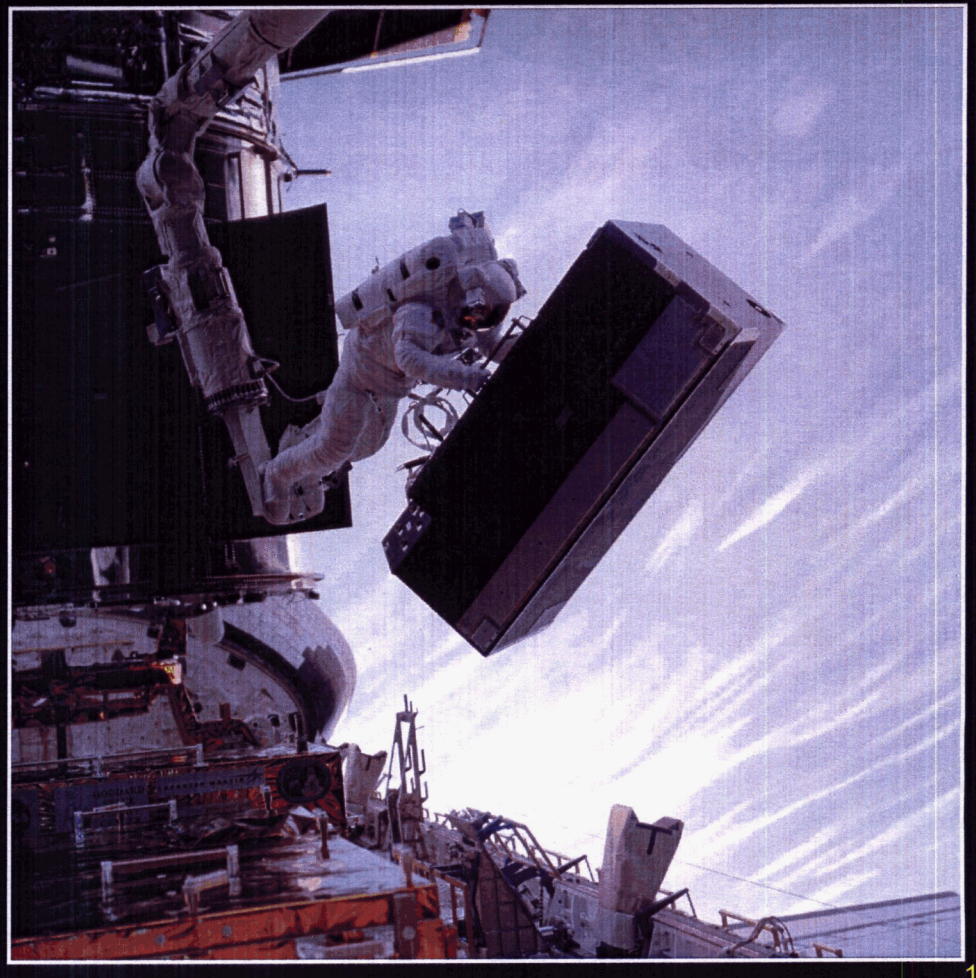
Hubble Docked with Endeavor



Hubble Telescope

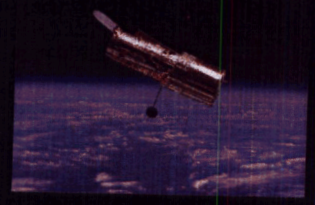


Wide Field Planetary Camera

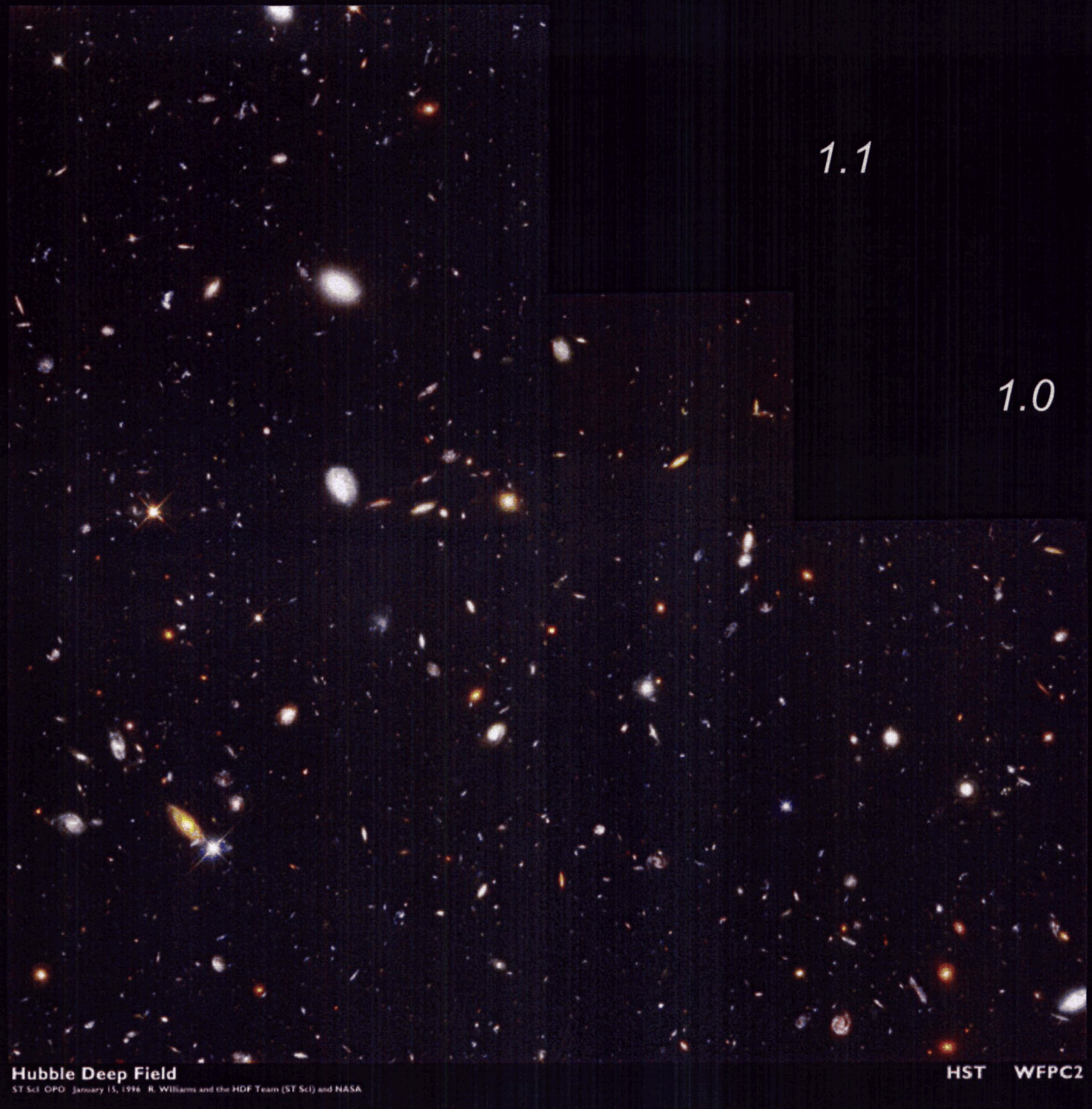


High Resolution Spectrograph

The Early Universe



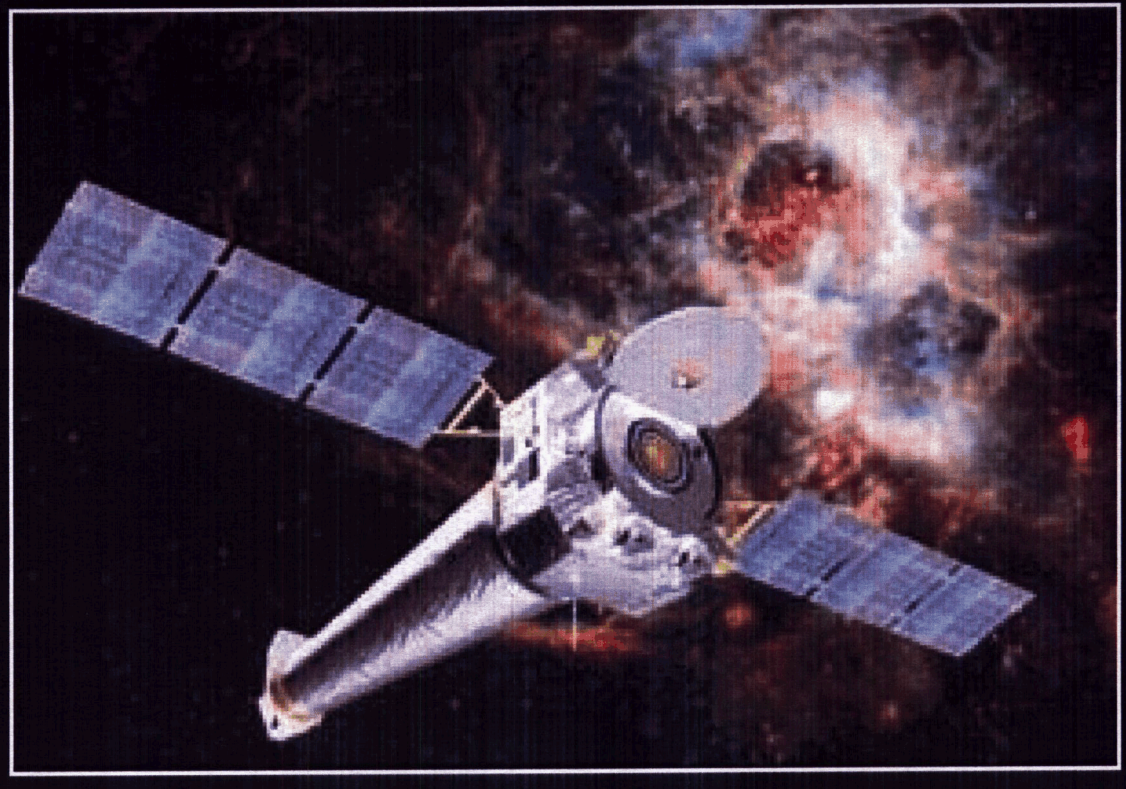
The Hubble Deep Field



STScI Science Project: Robert Williams. et al. (1997)

Hubble Ultra Deep Field
Advanced Camera for Surveys

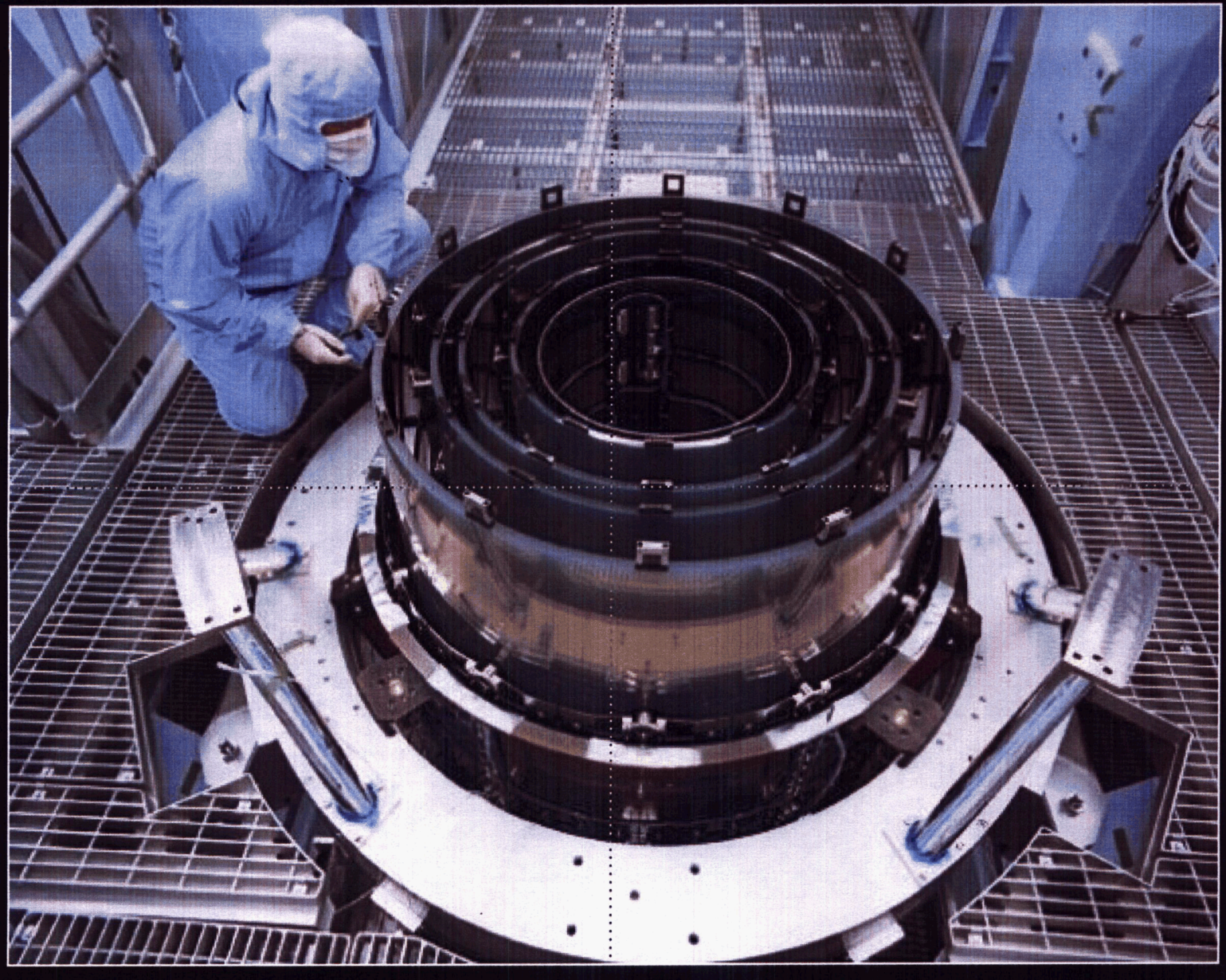
Chandra X-Ray Observatory



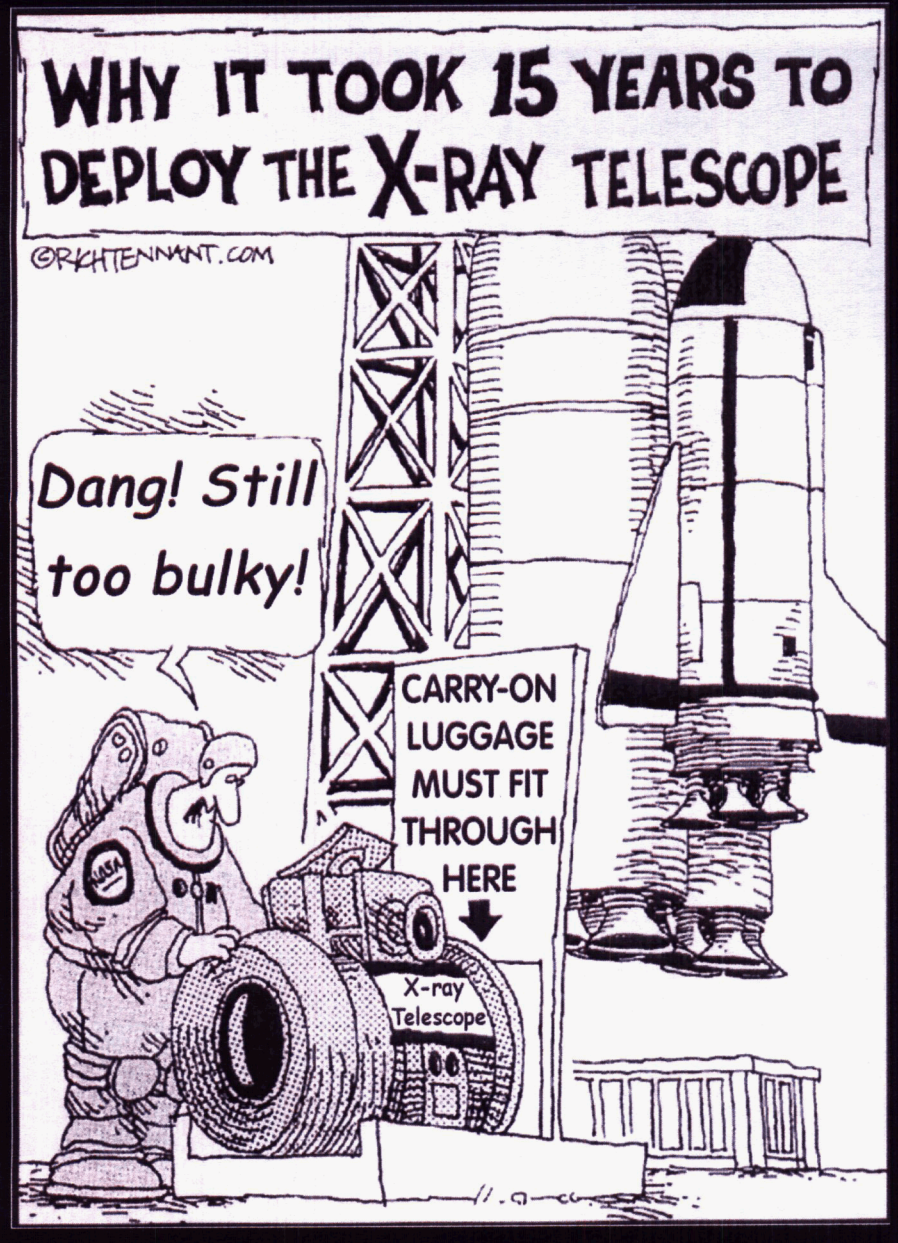
Chandra Spacecraft With Cassiopeia A Background

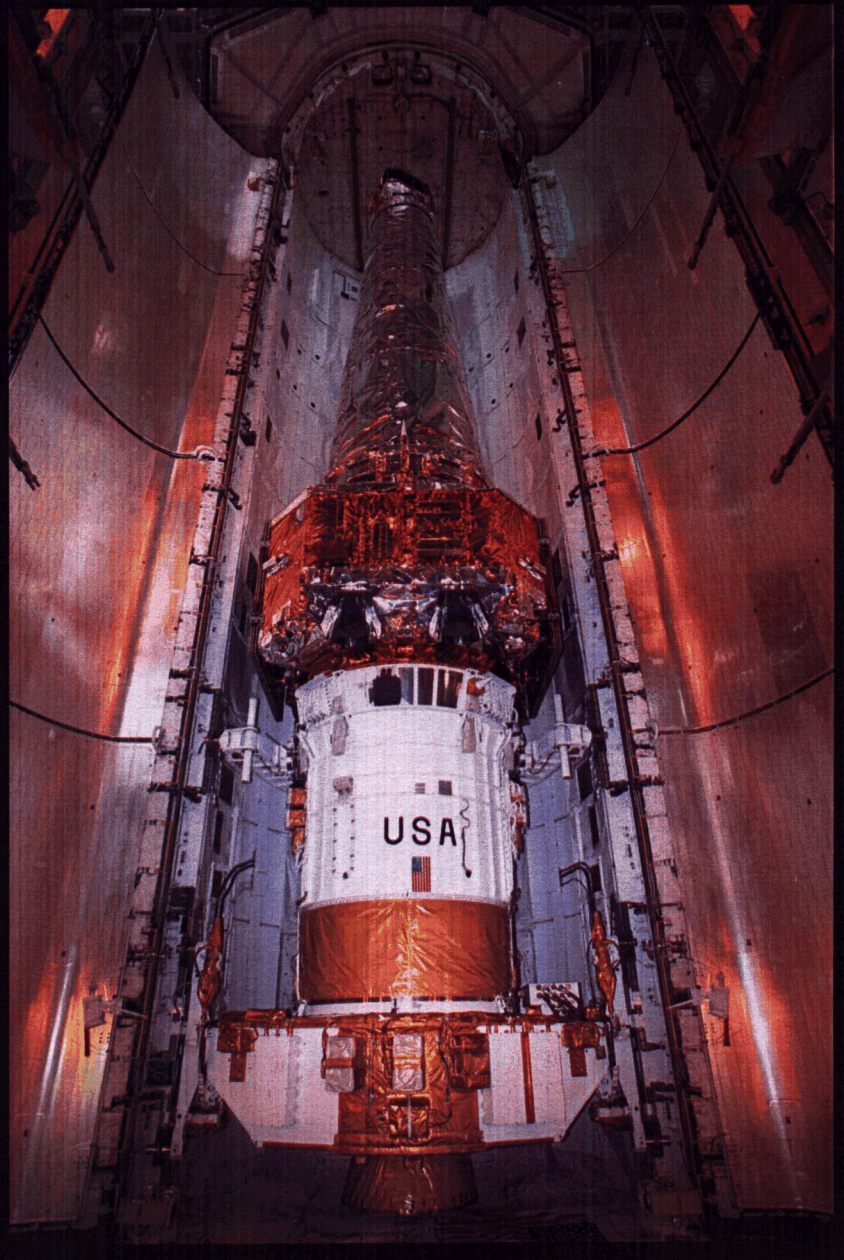
PKS 0637

Optics



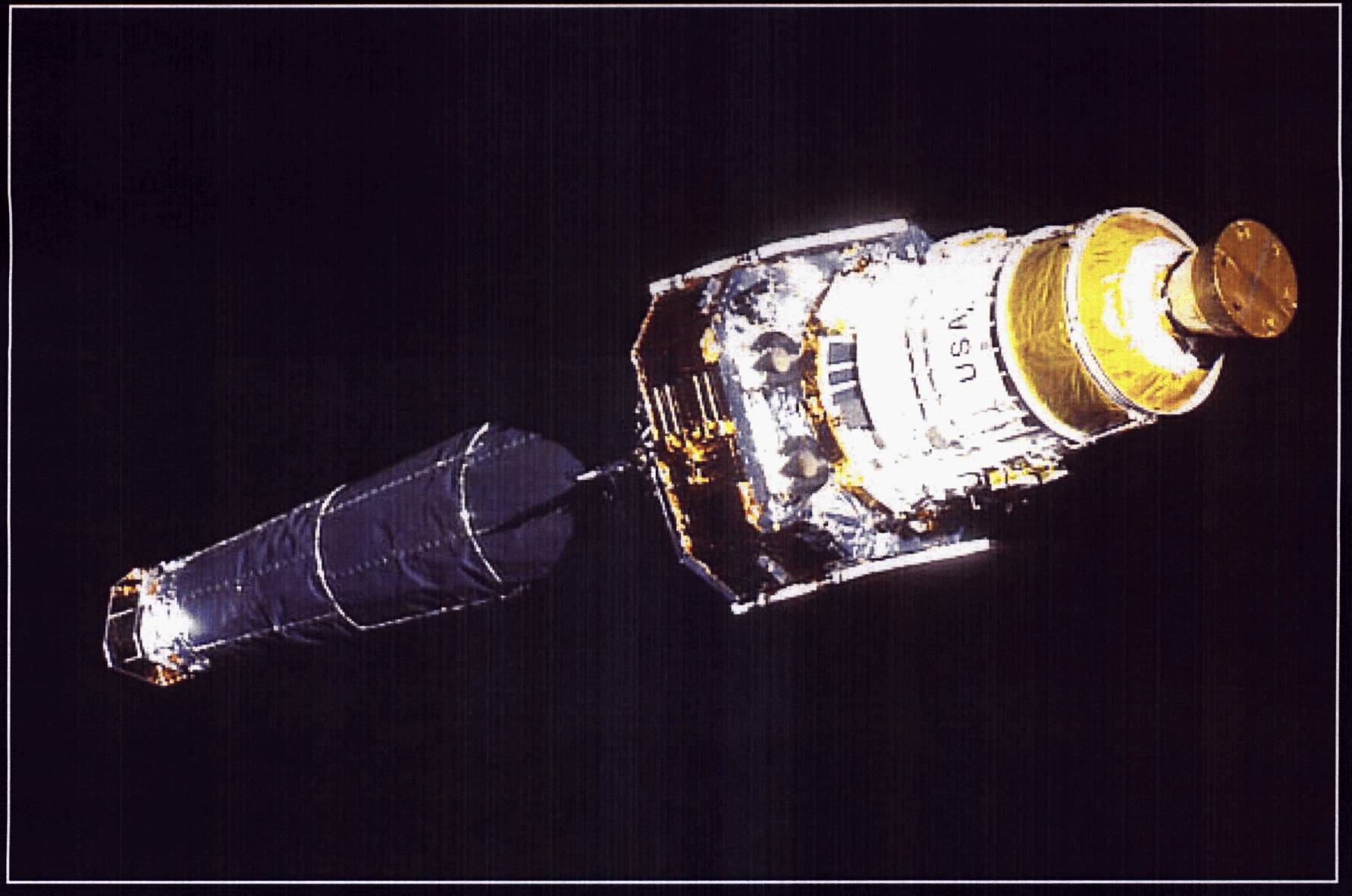
Chandra in Cargo Bay



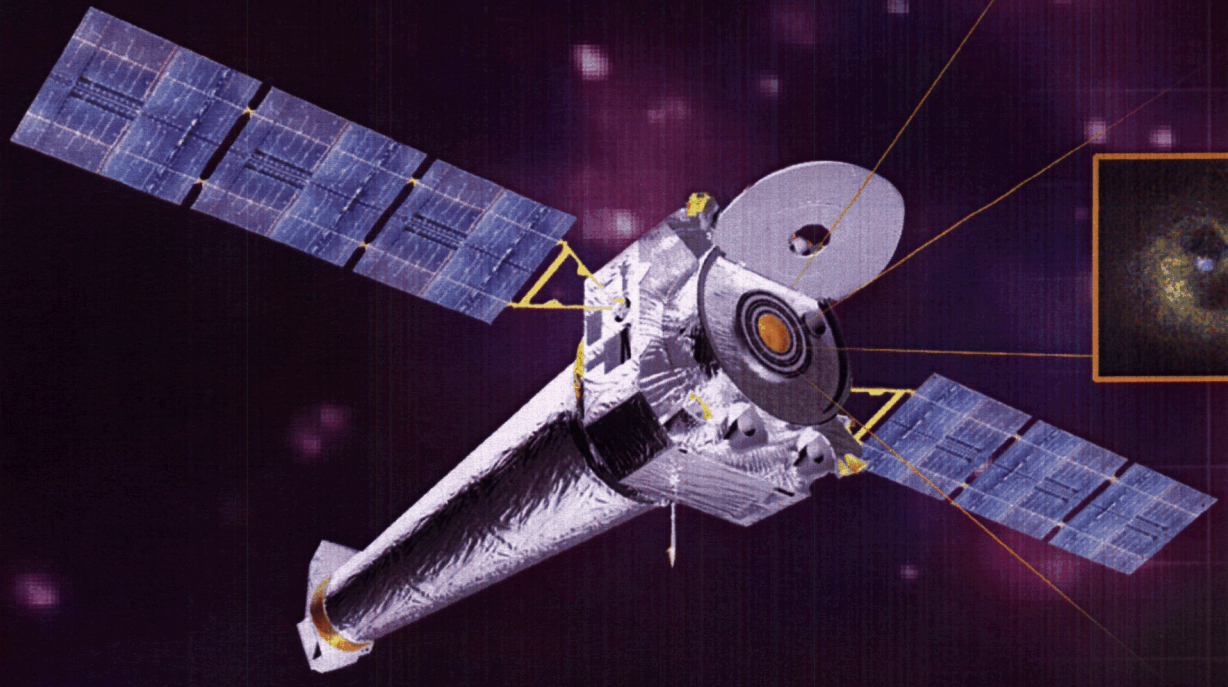


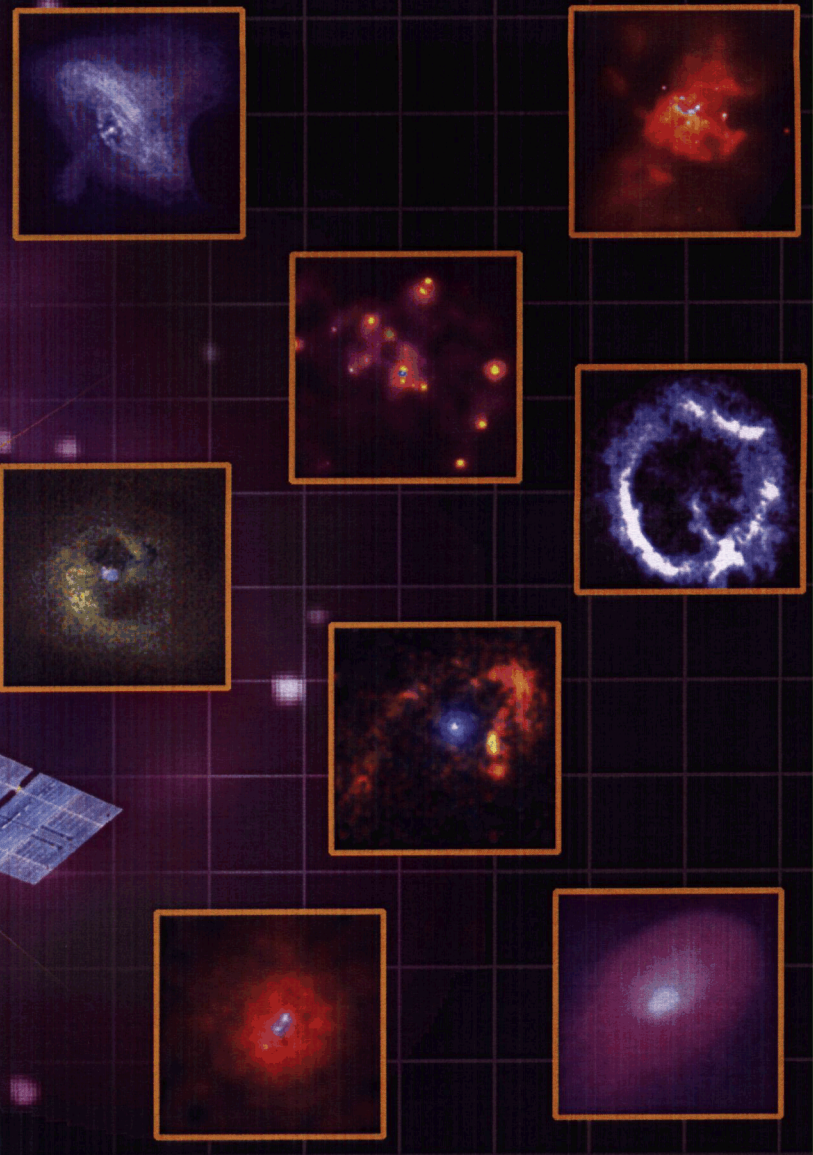
Chandra X-Ray Observatory

Deployment of Chandra, July 23, 1999



One Year Later...

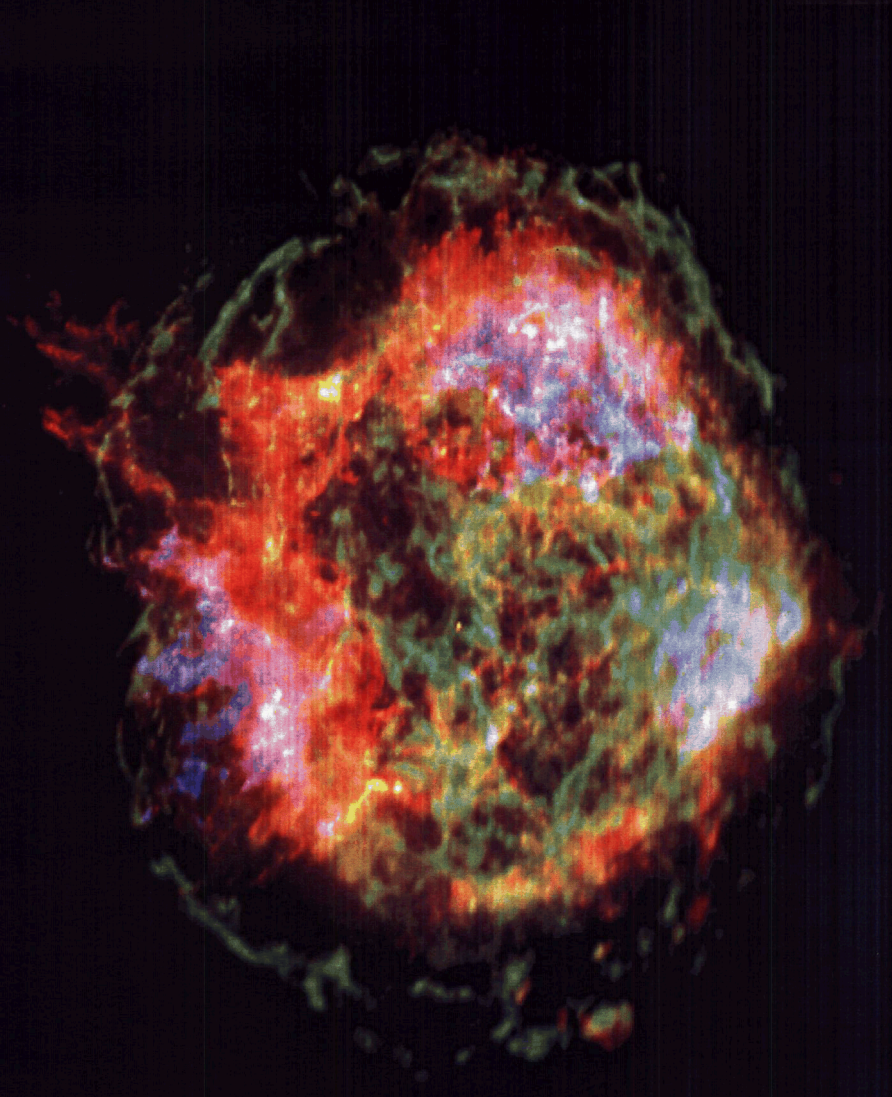




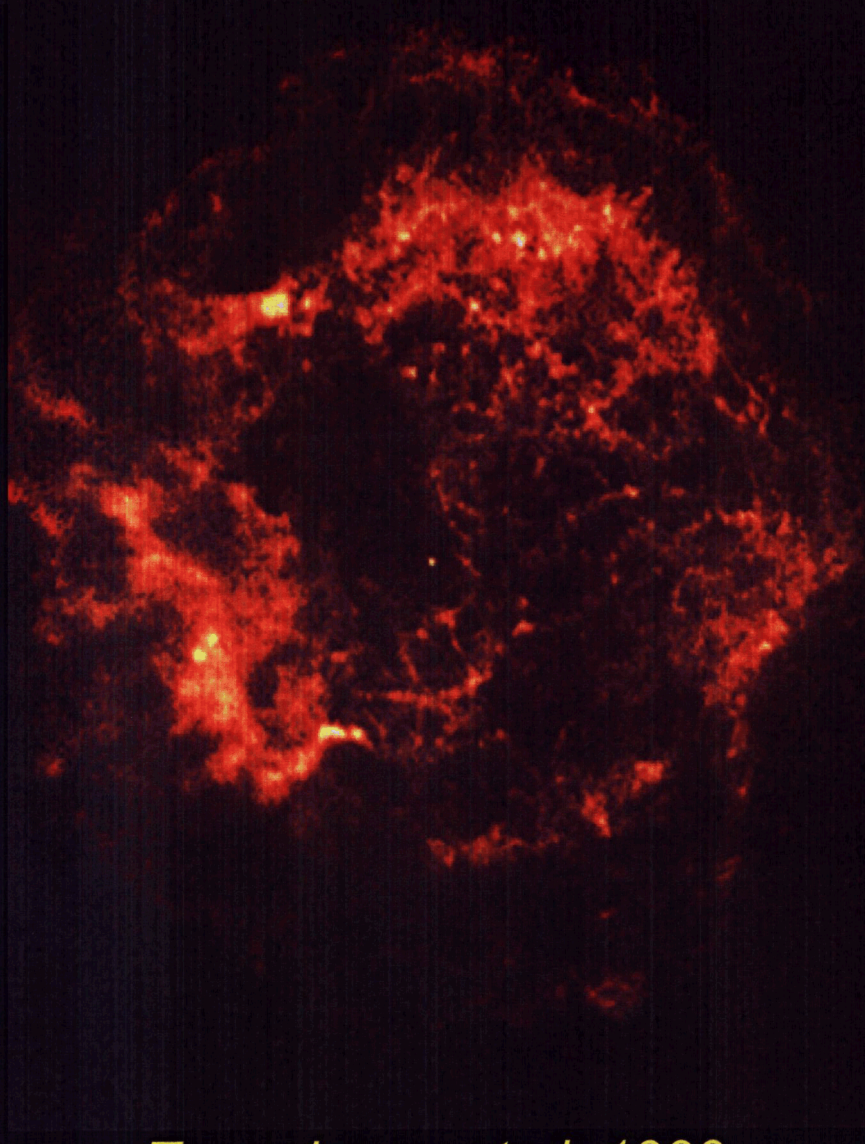
Chandra X-Ray Observatory

http://chandra.harvard.edu

CASSIOPEIA A

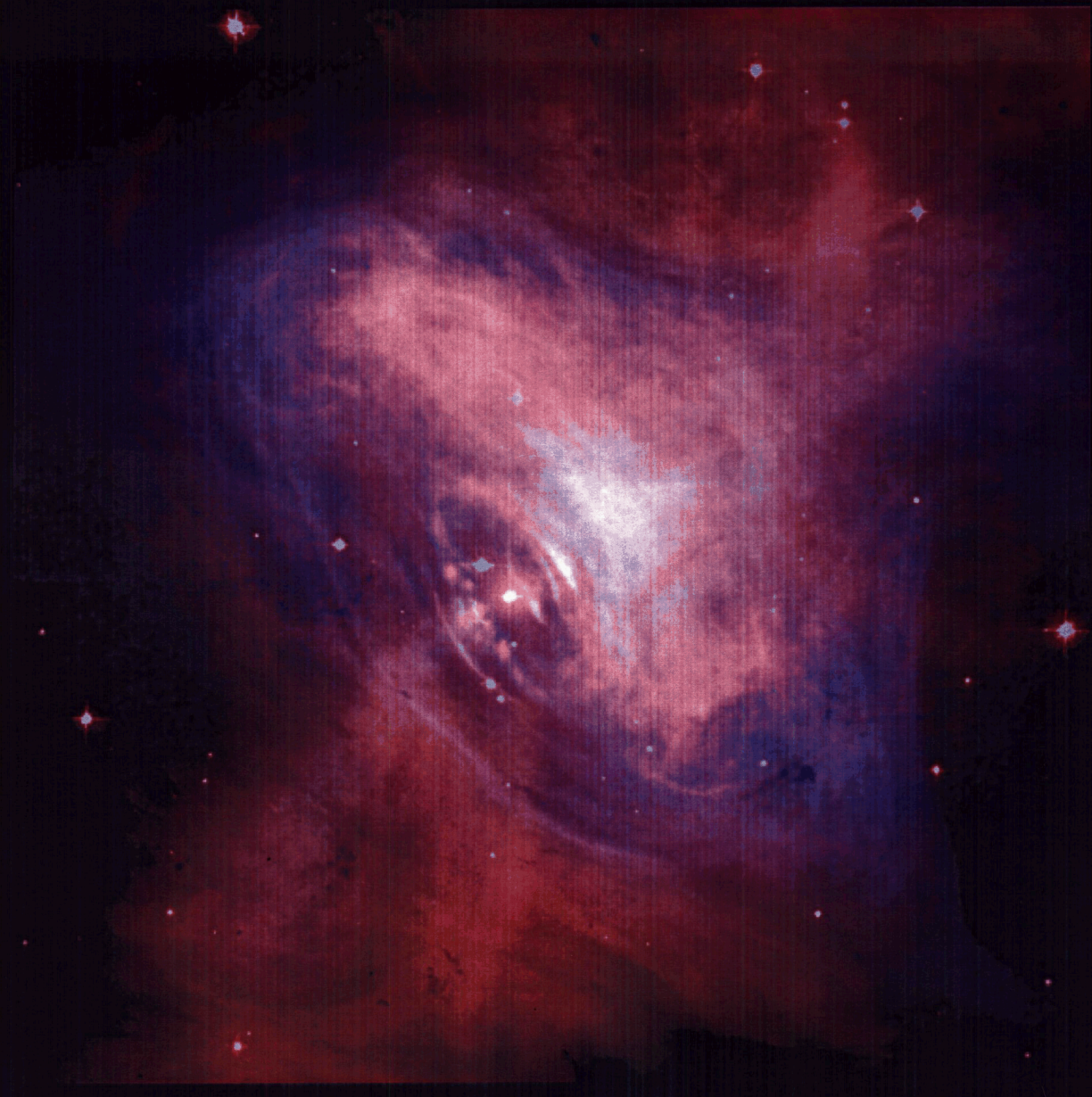


Hwang et al. 2004



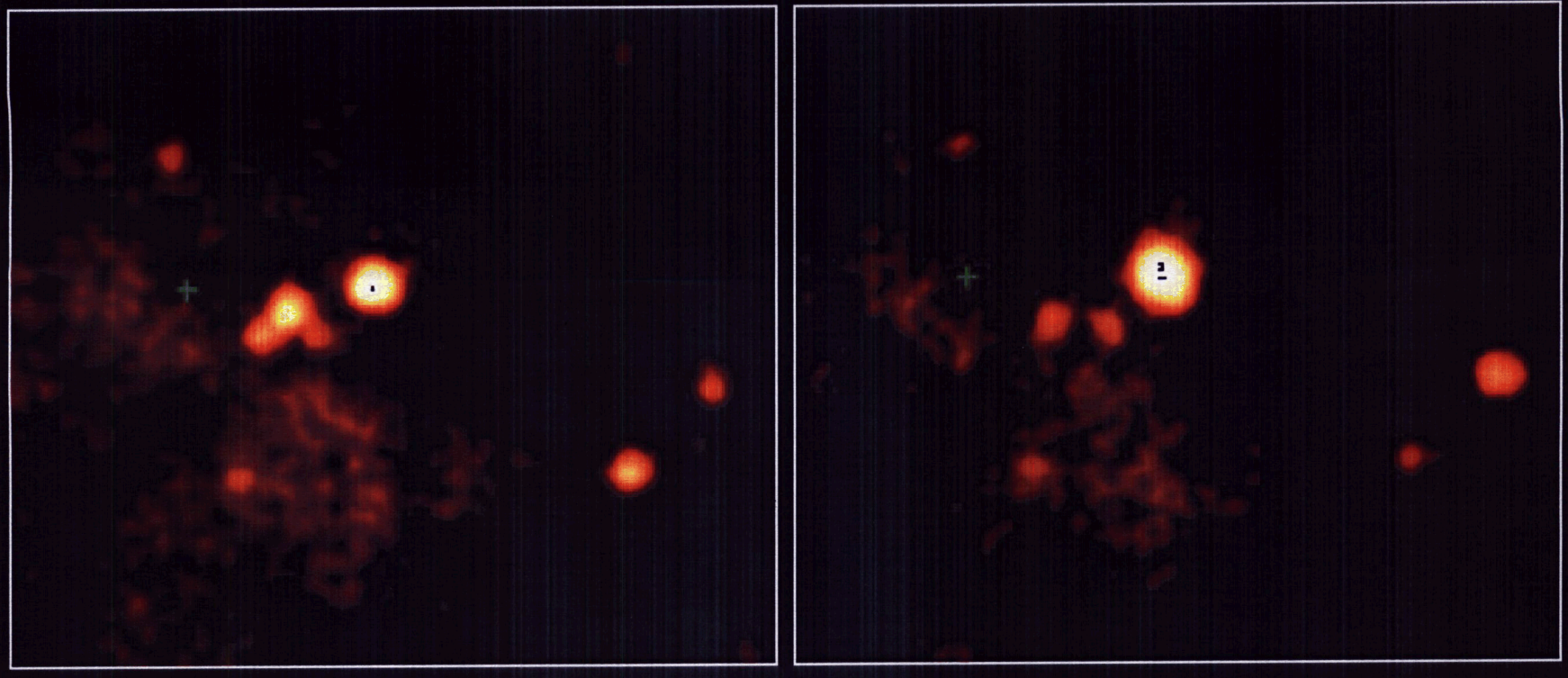
Tananbaum et al. 1999

CRAB NEBULA



Weisskopf et al. 2000; Hester et al. 2002

M82 Black Hole




NASA
Chandra X-ray Observatory

X-Ray Astronomy Roadmap

MAXIM
10 Million times finer imaging

0.1-1.0 m²
0.1 micro arc sec

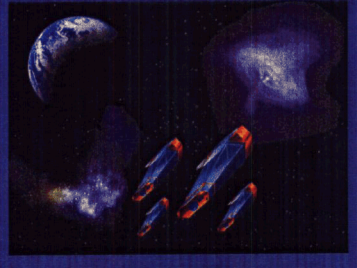
Chandra

XMM-Newton

Astro-E2

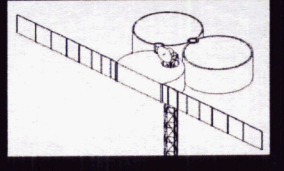
0.1-0.35 m²
0.5-90 arc sec

Constellation-X
20-100 times increased sensitivity for spectroscopy



3 m²
5-15 arc sec

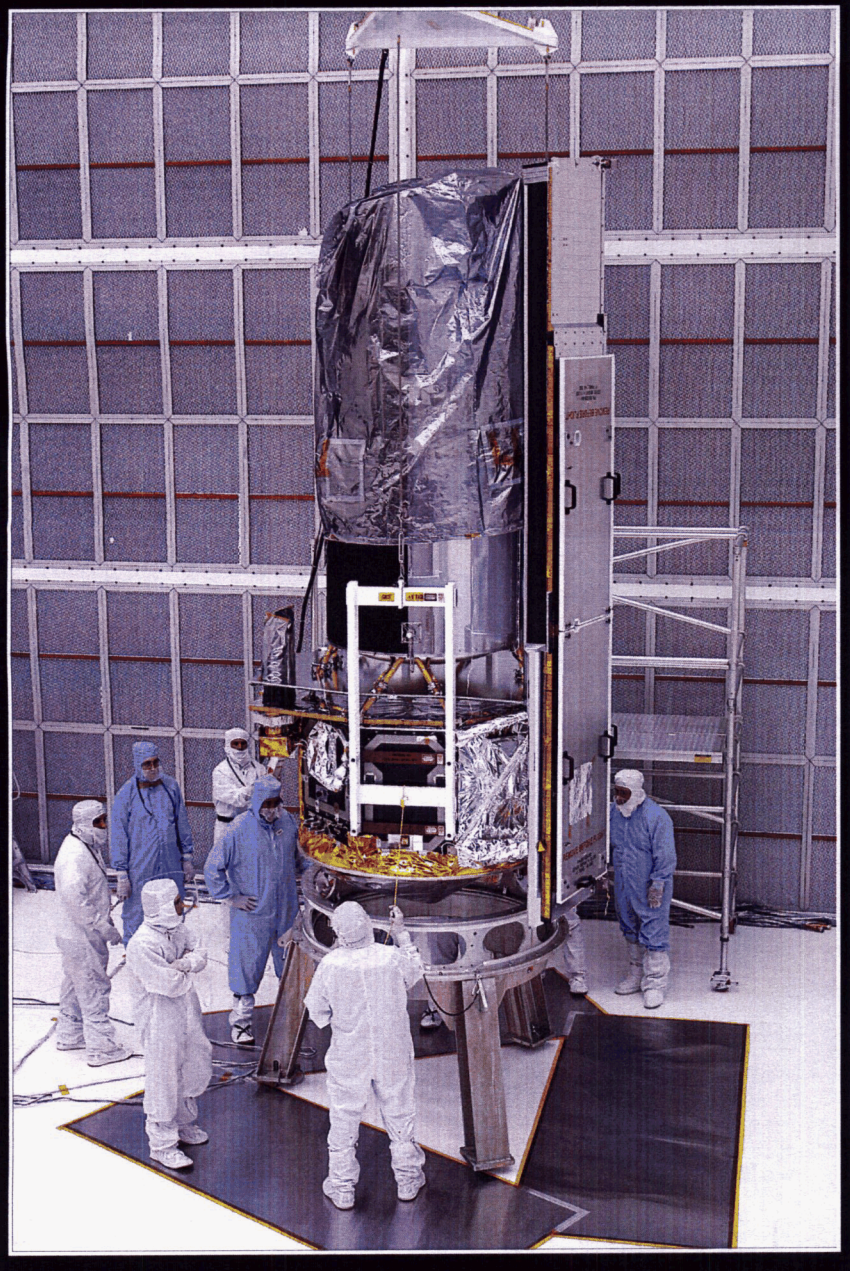
Generation-X
1000 times deeper X-ray imaging

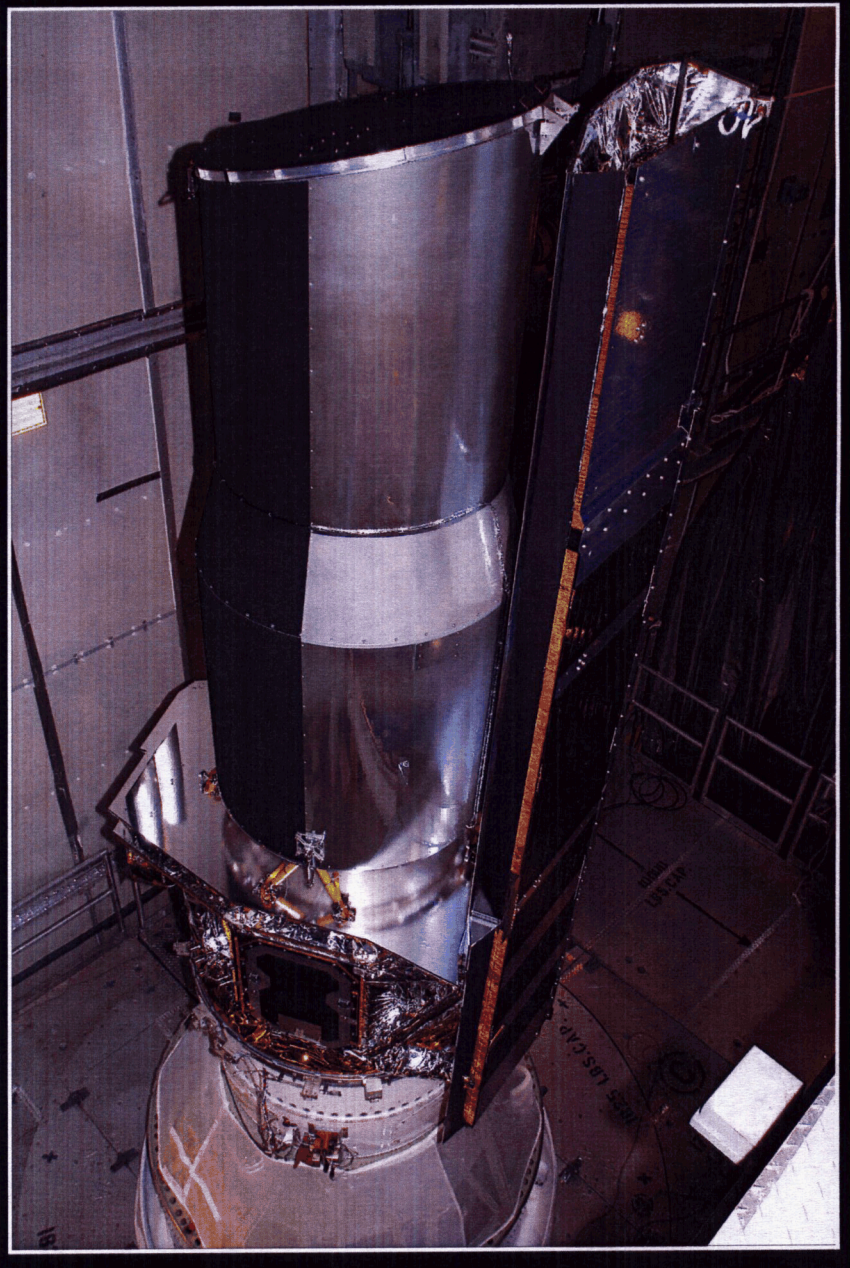


50-150 m²
0.1-1 arc sec

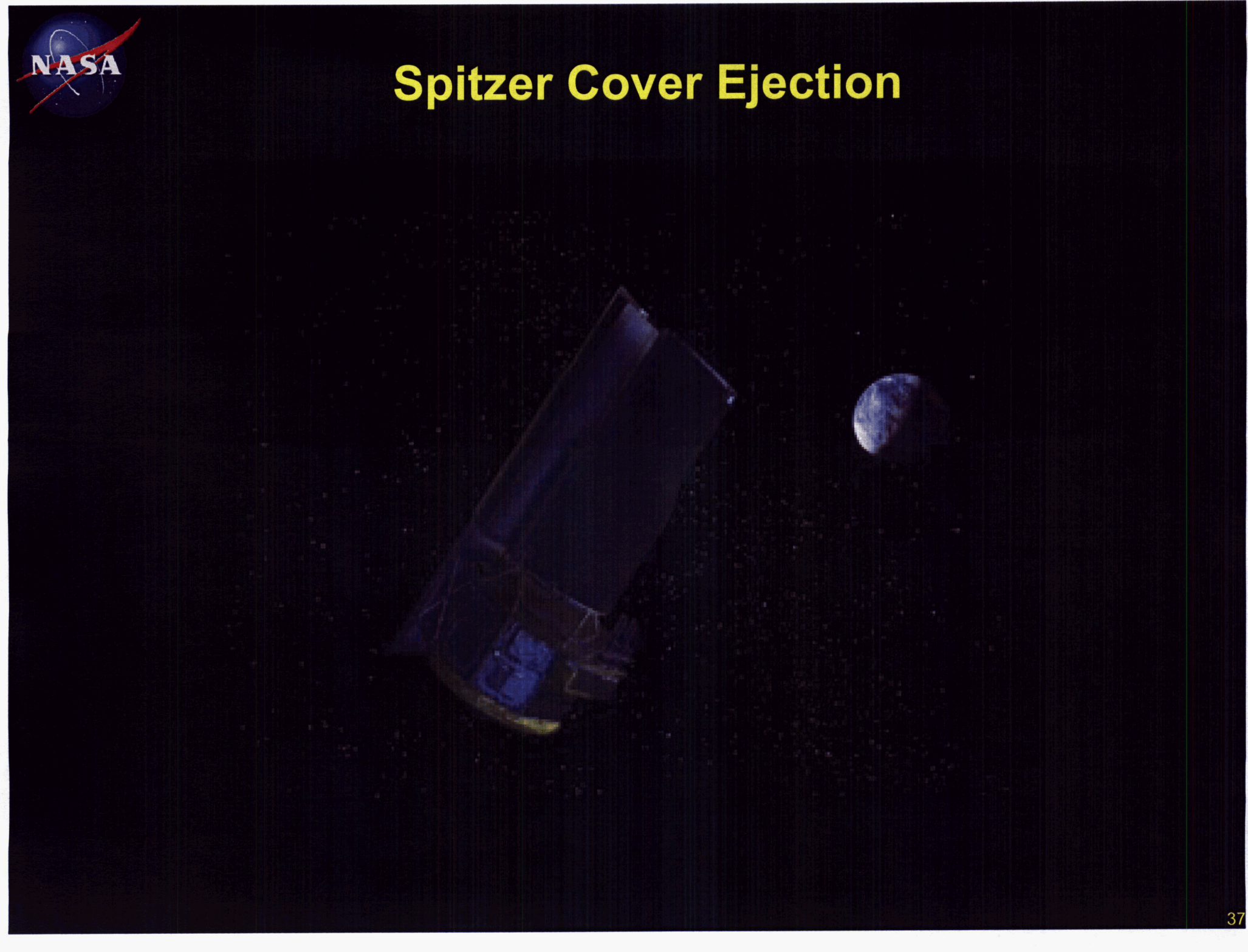
Constellation-X endorsed by NAS McKee-Taylor Survey & Q2C report as high priority mission for this decade

Lyman Spitzer Telescope

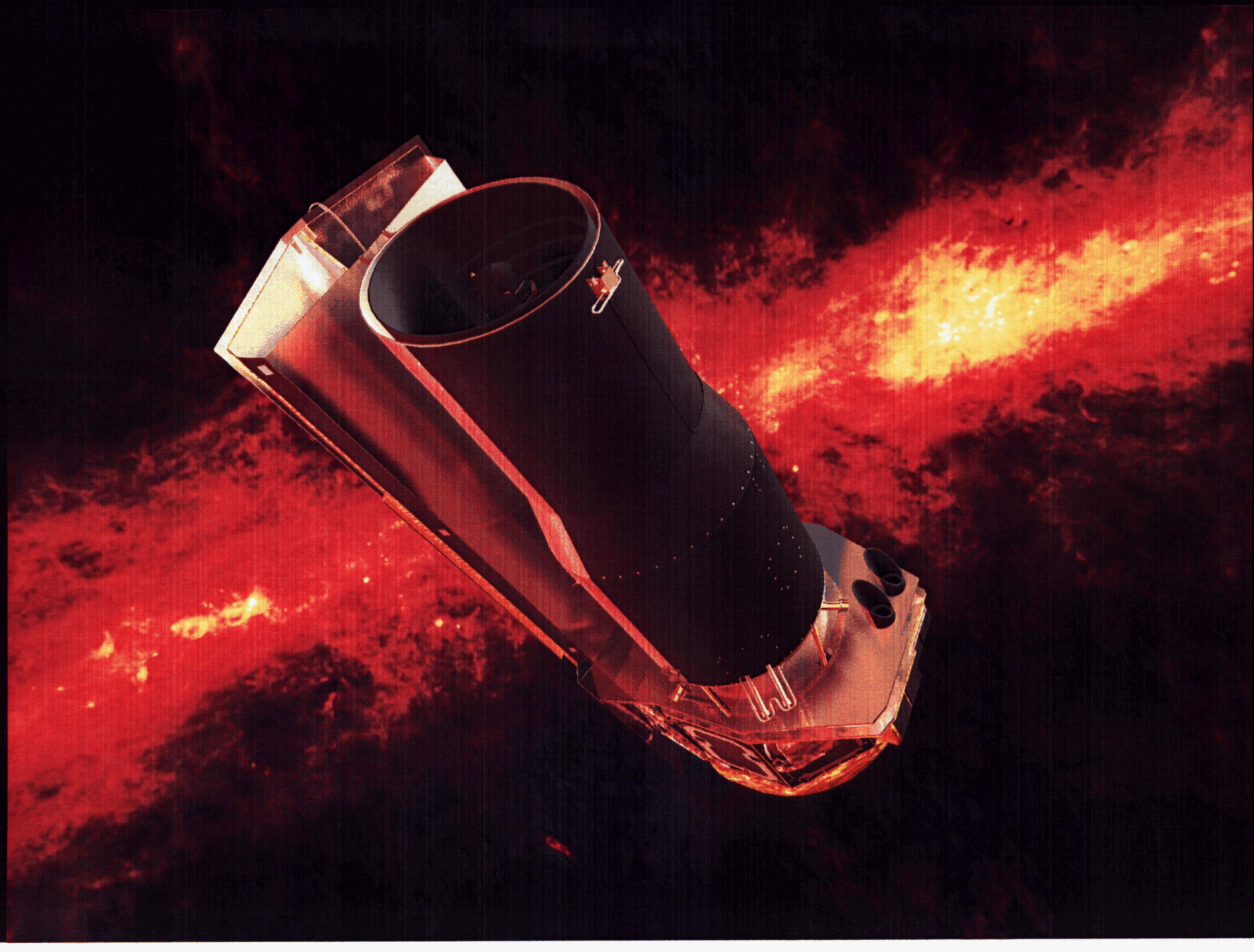




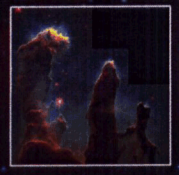
Spitzer Cover Ejection



Lyman Spitzer Telescope



Lyman Spitzer Telescope

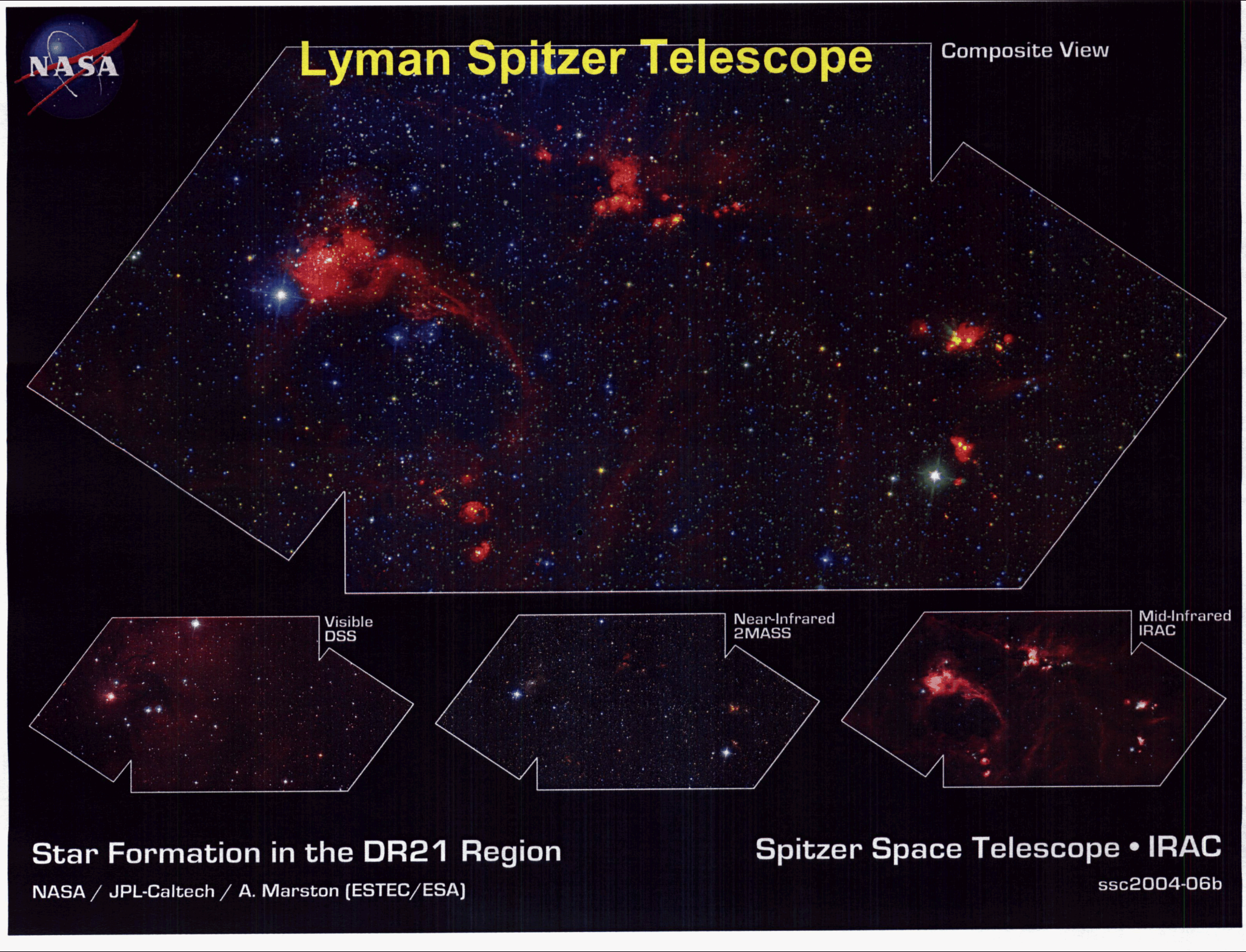


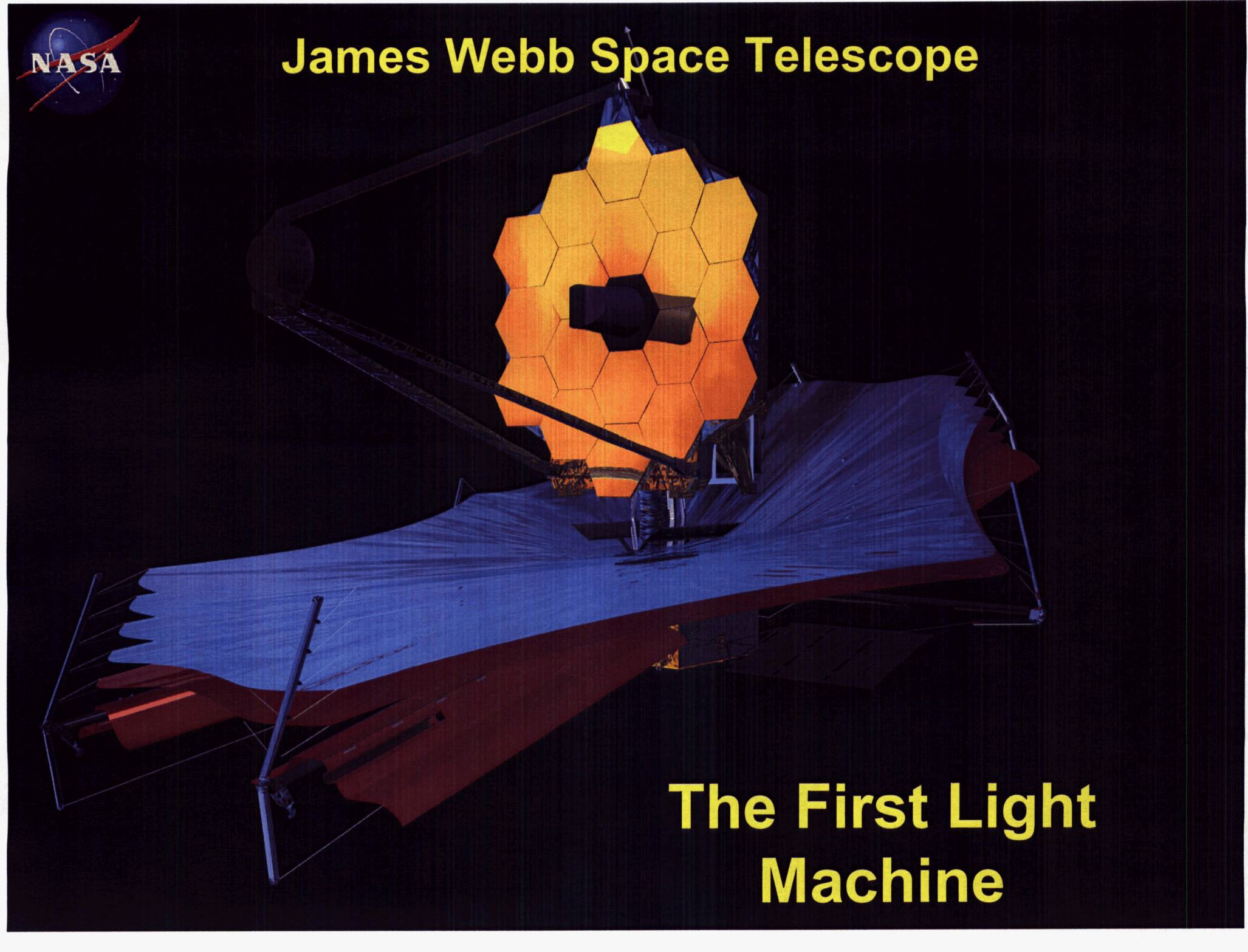
Hubble's "Pillars of Creation"
[shown to scale]

"Pillars" and "Mountains" of Star Formation

Spitzer Space Telescope • IRAC
Inset: Hubble Space Telescope
ssc2005-23b

NASA / JPL-Caltech / L. Allen (Harvard-Smithsonian CfA)

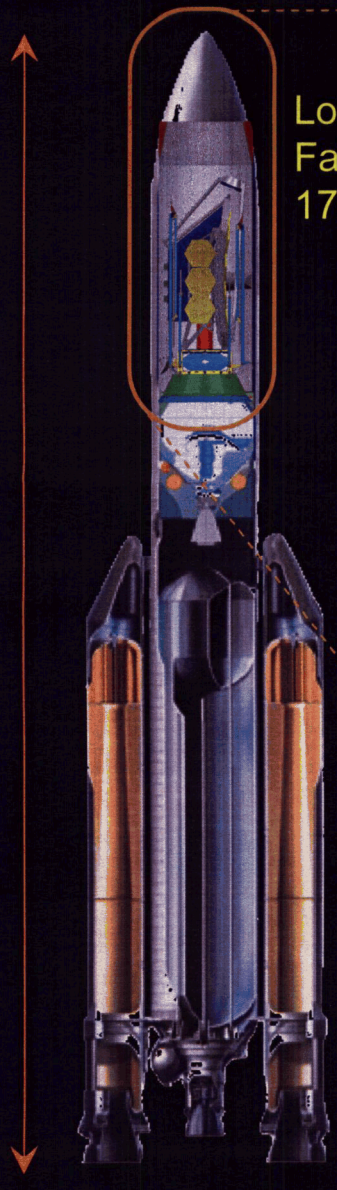

NASA
Lyman Spitzer Telescope
Composite View
Visible
DSS
Near-Infrared
2MASS
Mid-Infrared
IRAC
Star Formation in the DR21 Region
NASA / JPL-Caltech / A. Marston (ESTEC/ESA)
Spitzer Space Telescope • IRAC
ssc2004-06b

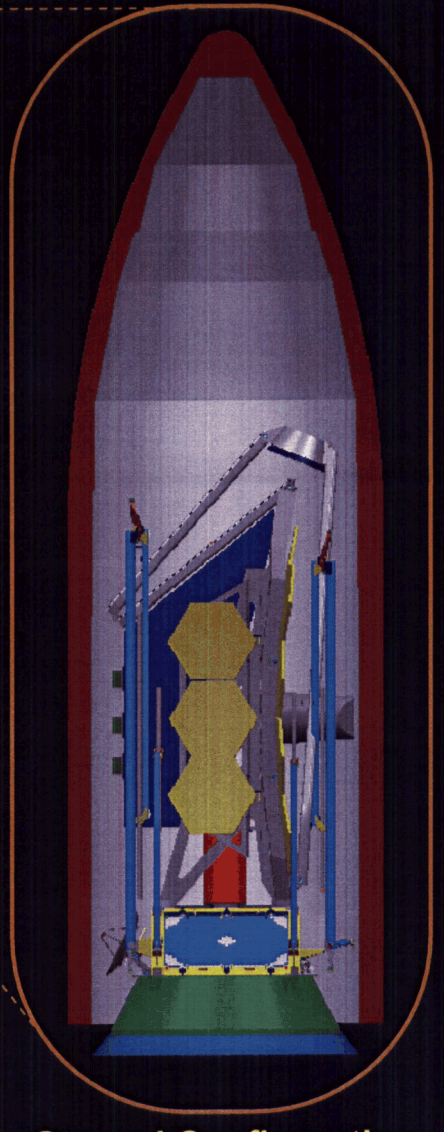

NASA
James Webb Space Telescope
The First Light Machine

Full Scale JWST Mockup

21st National Space Symposium, Colorado Springs, The Space Foundation

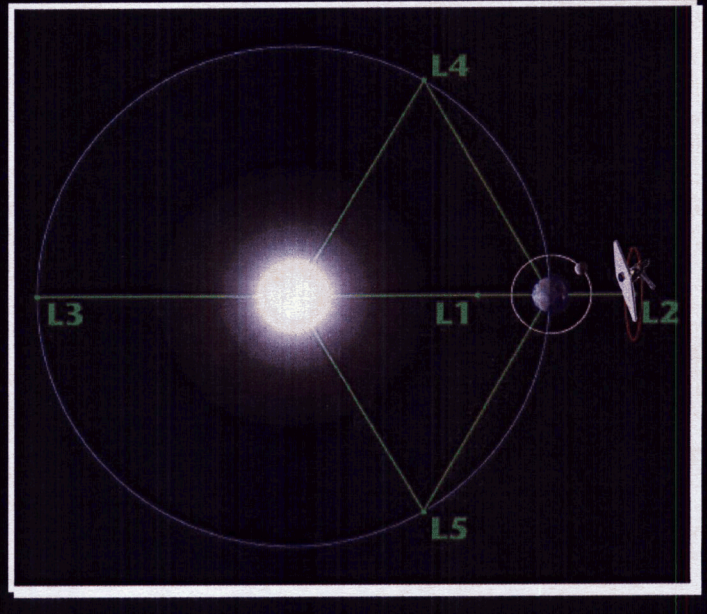
JWST Launch and Deployment

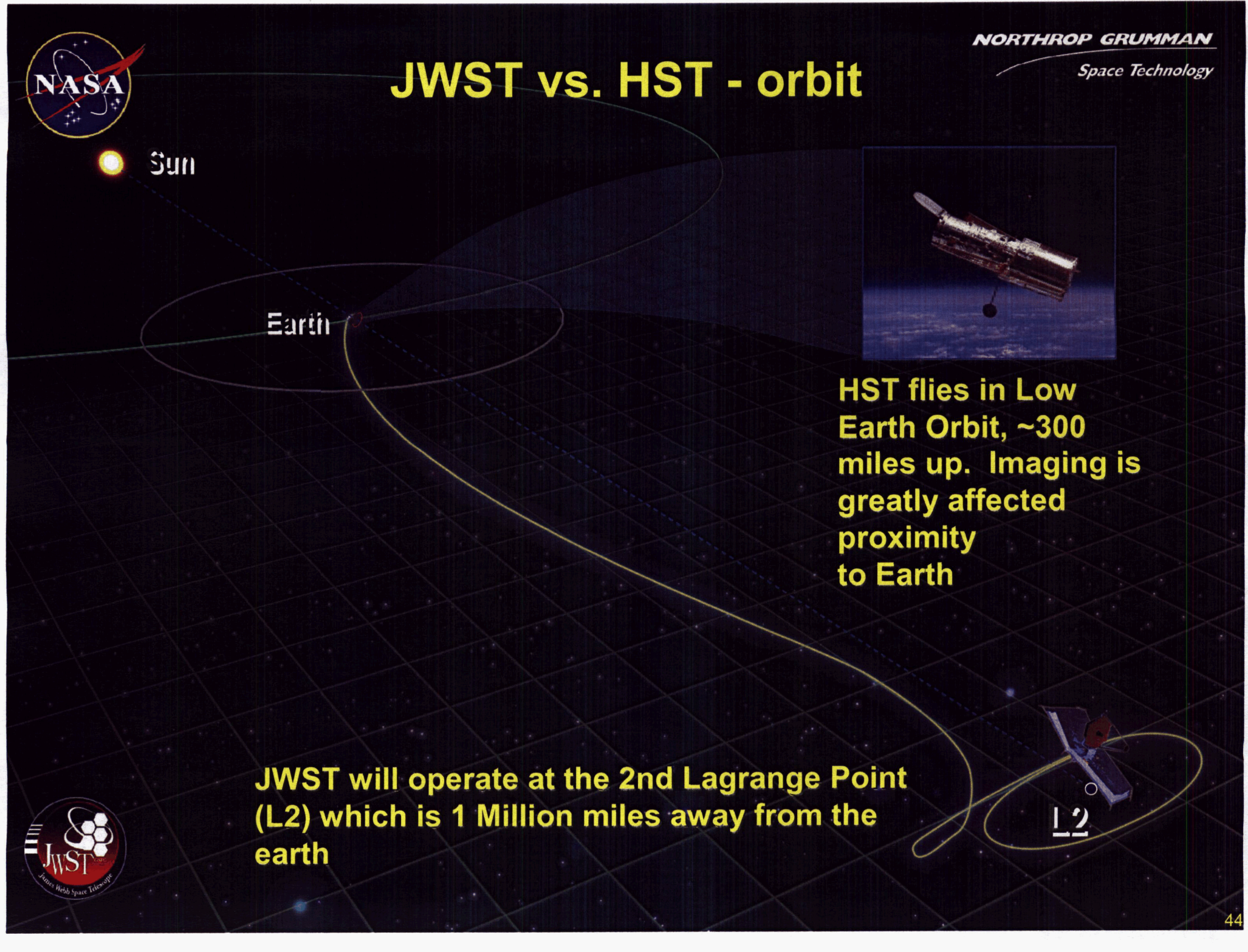




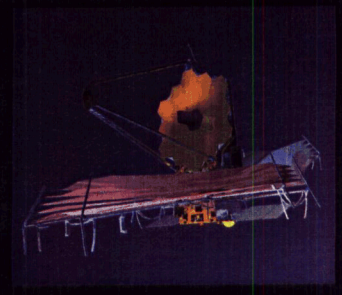
Stowed Configuration

- JWST is folded into stowed position to fit into the payload fairing of the Ariane V launch vehicle
- Several subsystems deploy during transit to its L2 orbit

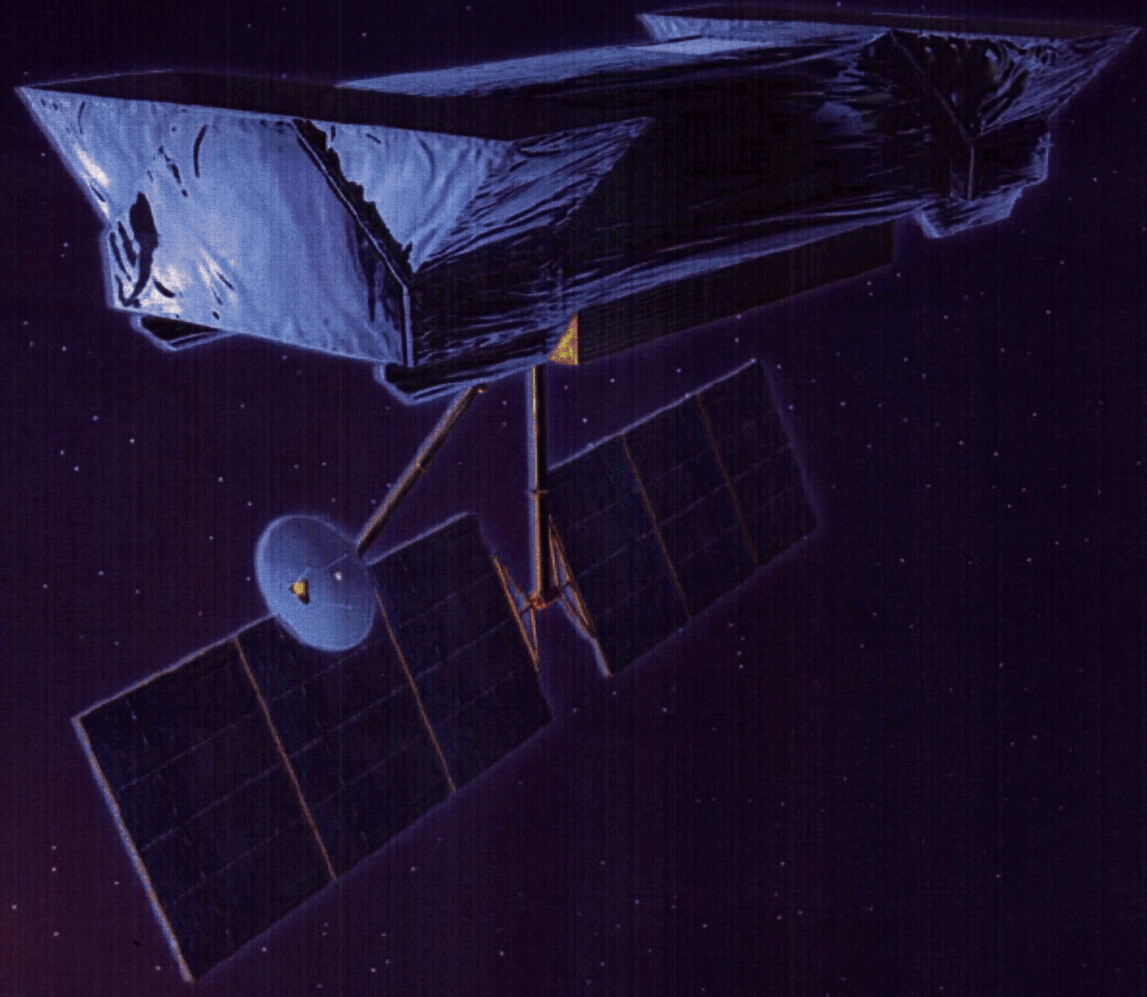



NASA
NORTHROP GRUMMAN
Space Technology
JWST vs. HST - orbit
Sun
Earth
HST flies in Low Earth Orbit, ~300 miles up. Imaging is greatly affected proximity to Earth
JWST will operate at the 2nd Lagrange Point (L2) which is 1 Million miles away from the earth
L2
JWST
James Webb Space Telescope

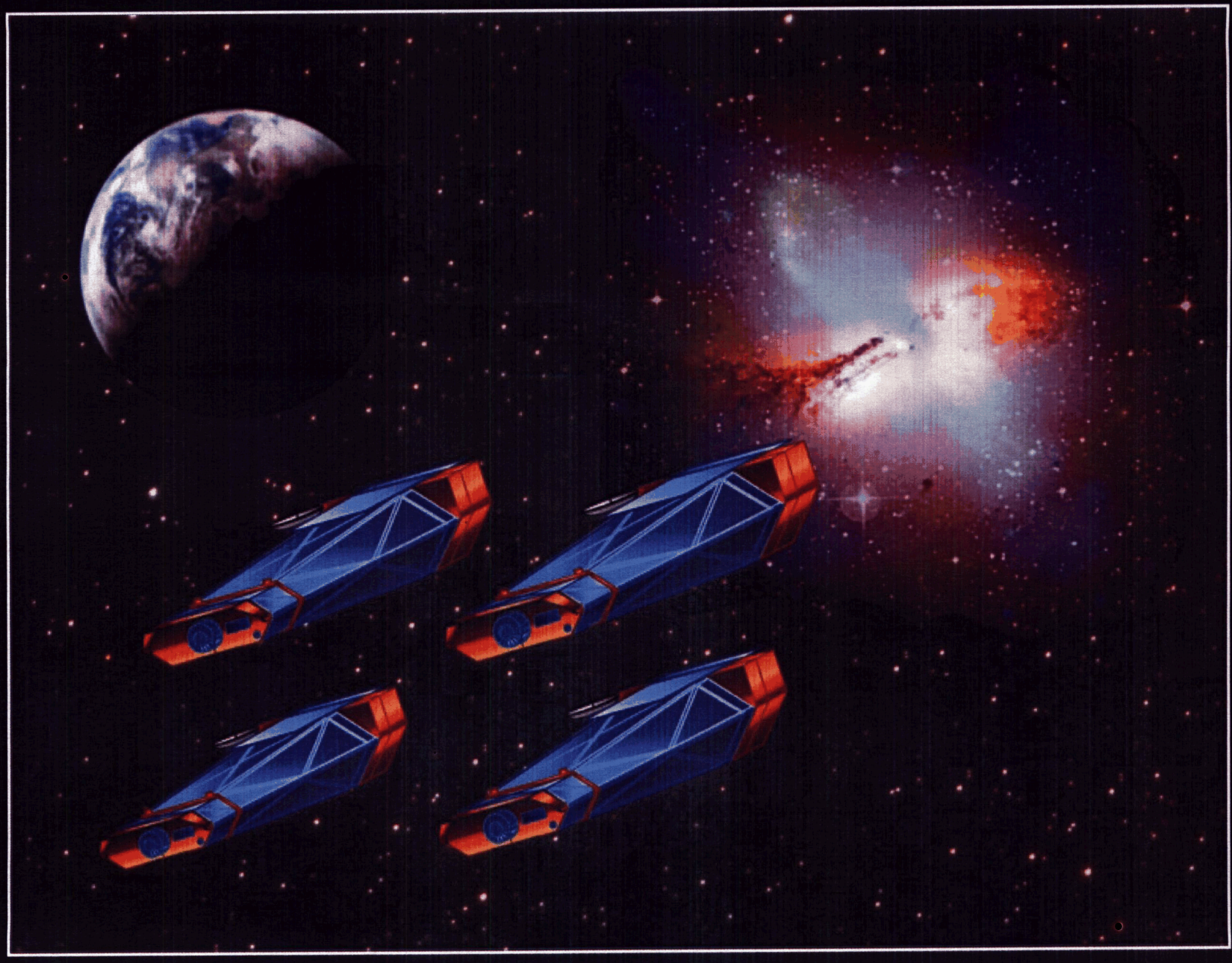
JWST Deployment



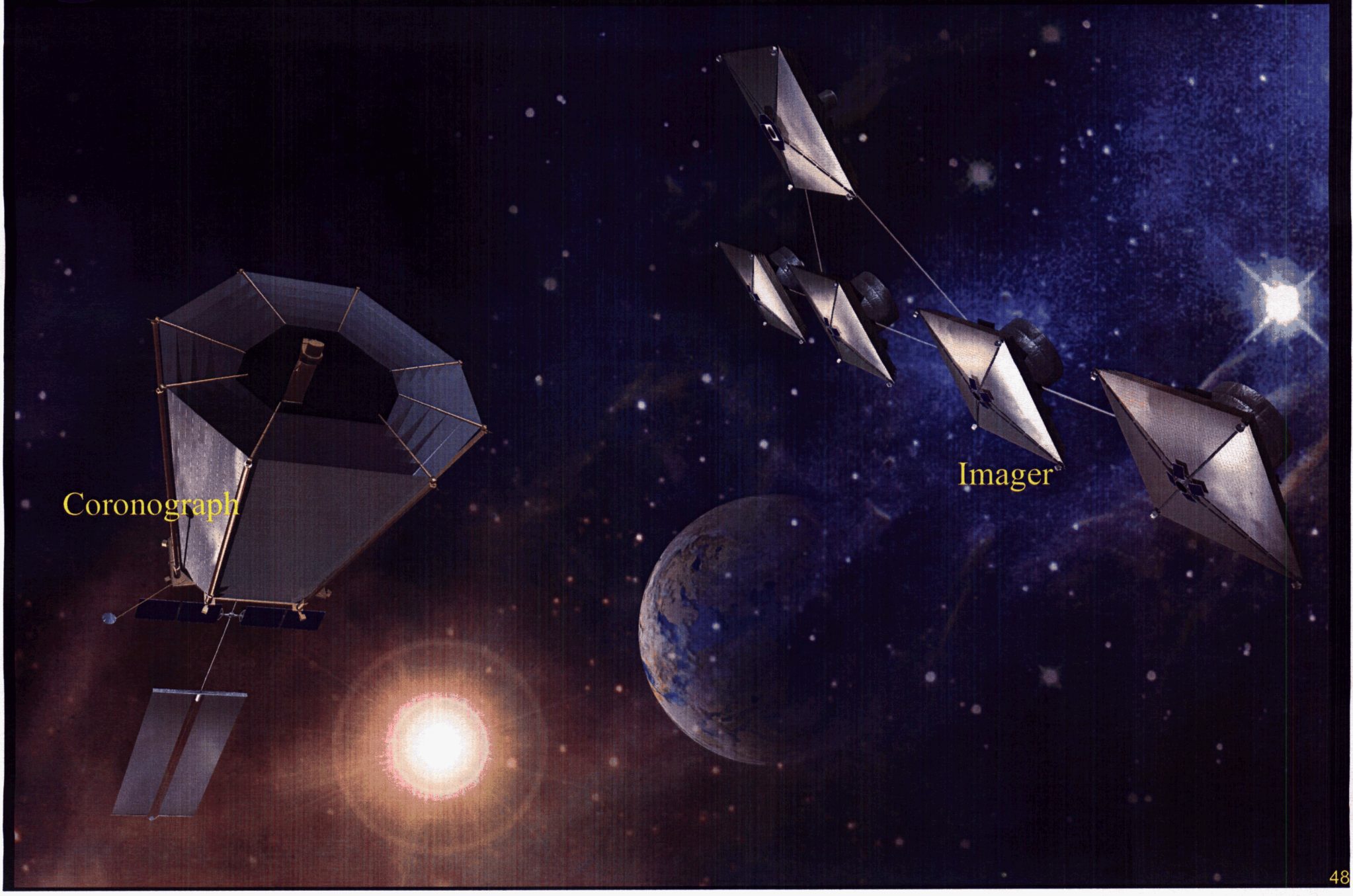
Space Interferometer Mission



Constellation X-ray Mission

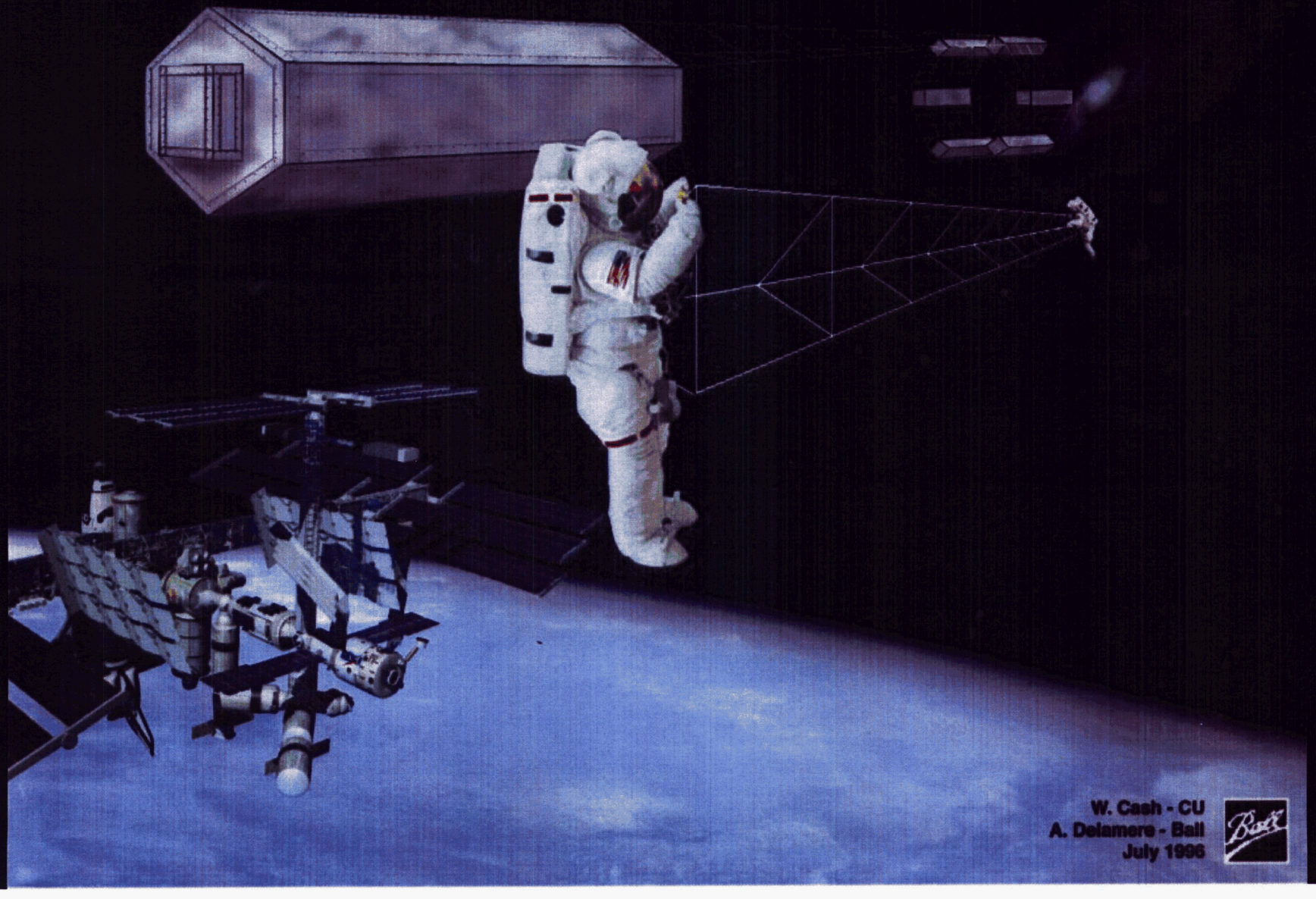


Terrestrial Planet Finder



Micro Arcsecond Interferometer X-Ray Imager/Spectrometer

1 micro arcsecond Interferometric X-ray Imager/Spectrometer



W. Cash - CU
A. Delamere - Ball
July 1996

Terrestrial Planet Imager